ASSESSMENT OF NOISE EFFECTS AT WORK PLACE

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by

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Table of Contents

Table of Figures

Table Of Tables

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DECLARATIONS

Declaration by the Candidate

I hereby declare that I am the author of this thesis; that I performed the work described herein; that other contributors to the work hae been suitably acknowledged within the text. I also declare that this thesis has not been submitted for any other degree.

[redacted]

Faisal A. Al-Sharifi

Declaration by the Supervisor

I certify that Mr Faisal A. Al-Sharifi has satisfied the terms and condition of the relevant Ordinance and Regulations of the University of St Andrews.

[redacted]

Dr David Watt

ABSTRACT

Noise is considered to be a physical form of environmental pollution which can influence the health of exposed persons. Excessive exposure to noise can interfere with performance at work and with the ability to relax or sleep. Also it may impair hearing and it can evoke other phsyiological and pathological symptoms to the detriment of health. The sources of noise may be local or general. Industrial processes are an important source of indoor or localised noise. Persons exposed to noise as a consequence of their employment are legally protected to some extent by European Directives and National Regulations which limit the maximum permissible noise levels to 85-90dB. A research project was launched with the full co-operation of the Don and Low Group of Companies, Forfar and Perth, Scotland.

Study indicates that the proportion of employees who have noise-induced hearing loss is higher amongst those who work in higher than 85dB, (e.g. Group 1 <85dB-11%; Group 2 85<90dB-44%; Group 3 90<95dB-44%; Group 4 ≥95dB-39% = 138% in total). In all groups social and economic status, sex, age and average number of years' service are almost identical.

In general, the study indicates a higher number of employees suffered from ear problems between groups exposed to 85dB and more, (e.g. perforated eardrum, noise tinnitus , vertigo, wax in ears).

The danger of noise has been studied in detail regarding the general health of employees as follows:

1. *Sleep disturbance*

   It appeared that most of the cases who suffered from sleep disturbance were found amongst employees exposed to greater than 85dB, averaging about 33%. On the other hand, only 8% of the employees in category <85dB complained of sleep disturhbance.

2. *Blood Pressure*

According to job categories 10% of employees had heart problems in job category higher than 85dB, but only one case reported heart problems in job categories less than 85dB.

3. *Stress*

Smoking was one of the subjects studied in detail in this project and the results were significant. An average of 40% of employees were smokers among groups exposed to higher than 85dB compared to 10% of smokers among employees exposed to less than 85dB.

Industrial accidents occur at a higher rate among employees who worked in noisy environments (≥85dB) with regard to reported or unreported accidents.

From the result of the research, industrial noise should be studied in a more comprehensive way to measure all effects of noise regarding employees health by using the statistical data and always noise should be controlled at source.

Industrial noise is still a major danger to employees. From the results in this study it appears there is a need for more co-operation between employer and employee and not just depend on the health and safety regulations and try to solve the problem.

CHAPTER 1

OBJECTIVES AND PLAN OF STUDY

1.1 INTRODUCTION

Noise in industry is widespread even though there are indications from the Industrial Injuries Scheme that cases of occupational deafness have peaked (HSC - Health & Safety Commision, 1992). NIHL (noise induced hearing loss) and other ear disorders consistute the second most frequent category in the Prescribed Diseases Statistics in the UK with 1041 assessed claims in 1990-1991 (Employment Gazette, 1992). In addition, in the 1990 Labour Force Survey 100 000 respondents reported that they suffered from deafness or other ear disorders 'caused' by work, the second in the league table of such complaints. In 1987 the Health and Safety Executive estimated that in the UK about 17 million people were exposed to 85dB(A) or over in their normal work (HSE, 1987), a level equivalent to the First Action Level given in the Noise at Work Regulations which were introduced on 1 January 1990. (Paul Lenster, Judith Baum, David Tong, and Carolyn Whitehead, 1994.)[1]

Since the early 80's little research has been carried out regarding the effect of industrial noise on the workforce. Therefore it was decided to carry out a comprehensive study of this area to investigate the relationship between industrial noise and health status. Arrangements were made to conduct the project at Don & Low because of their interest in the health of their workforce. A large number of workers at these plants received varying degrees of background noise over a sustained period.

The problem of noise pollution has been recognized since Roman times and should not be considered solely as a problem of our mechanized age.

Noise is considered to be a basic form of physical pollution of air. It can cause deleterious effects which interfere with the healthy development of people and it may interfere with performance of work, relaxation, sleep; affects hearing and can evoke other physiological and pathological reactions as well.

The sources of noise can be both local and general. Industry is an important source of indoor or localised noise to which occupants of confined places may be exposed.

Exposure may also occur in certain commercial places, eg night clubs. Noise is generalised when the whole environment is polluted. The main source of such generalised community noise is road traffic which may disturb a large proportion of the urban population. Aircraft noise is also of worldwide concern in that it may significantly affect the people living in the vicinity of airports.

In general, high noise levels are a feature of several forms of work environment, where long periods of occupational exposure may result in progressive loss of hearing.

Environmental noise, such as leisure activities, ie, shooting, loud music etc may interfere with satisfactory performance at work, and in time ultimately lead to health impairment.

Certain groups of people with reduced adaptability or reserve capacity are particularly vulnerable to, and need to be protected from, excessive noise. Examples are the aged and those with impaired sleeping function, or who are subjected to other environmental strains.

Noise is becoming a growing environmental problem, which needs to be studied in an attempt to plan a comprehensive control programme for protection of the community.

1.2 Noise in Industry

For hundreds of years, many people have, knowingly and unknowingly paid a high price for the effects of industrial noise eg, in permanent loss of hearing, high blood pressure, high accident rate and other disorders. (Waldron, H.A., 1989)[2]

Mechanised industry, which constitutes the most serious of all large scale noise problems, has subjected a significant fraction of the working population to potentially hazardous noise levels. This noise due to machinery of all kinds, may increase with the power of some machines. The characteristics of industrial noise vary considerably, depending on the type of equipment. For example, rotating and reciprocating machines, gasflows at high speeds (e.g. fans, steam pressure, relief valves) and by operations involving impaction (e.g. stamping, riveting and road breaking). In industrial areas, the noise usually originates from a wide variety of sources, many of which are of a complex nature (Peg, G., Line, J.A. 1995)[3] (Bandyopadjyay, 1994)[4].

1.3 Objective of Study

The objectives of this study are:

1. To assess the exposure to industrial noise at Don & Low
2. To determine the levels of hearing of exposed workers
3. To measure the effect of industrial noise on workers, ie, health in general, noise-induced hearing loss, noise awareness etc against other variables such as age, sex, environmental background, level of noise etc.

1.4 Plan of the Study

1. *To observe the working environment at Don & Low*
2. *To carry out an environmental noise survey for all the plants*
3. *To prepare and introduce a questionnaire to the workers covering different areas*
4. *To critically appraise the information, reach conclusion which are statistically supported and make recommendations.*

Chapter One deals with the aims and objectives of the study.

Chapter Two covers the company background, culture, environmental measuring systems etc with regard to Don & Low.

Chapter Three covers the literature review and methodology used.

Chapter Four covers environmental noise survey and recommendations for working environment at Don & Low plants.

Chapter Five basic statistics and demographic distribution of the employees at Don & Low plants.

Chapter Six analyses audiometry test results among exposed workers.

Chapter Seven deals with the statistical analysis of personnel questionnaires with regard to the effects of industrial noise.

Chapter Eight will be the recommendation and conclusion of the study.

CHAPTER 2

HISTORY OF DON & LOW

2.1 Company Background

Don & Low is the largest extruder and weaver of polypropylene yarns and fabric in the UK, and second largest in Western Europe. It is one of two trading subsidiaries of Don & Low (Holdings) Ltd, which is a wholly owned subsidiary of Shell Chemicals (UK) Ltd.

Based in Tayside Region, Scotland, Don & Low's involvement with the textile industry dates back to 1794, when a partnership was formed by John and William Don to spin and weave flax yarns. Ever since then, through nearly two centuries of change and evolution, the company has played a major role in shaping the nature of the industry itself. Anticipating and adapting to changing materials, technologies and markets has always been part of the strength of the company manifest in both the workforce and management.

2.2 Company Culture

Until recent years, the culture of the company was that of a business, built, owned and managed by members of local families, with decision-making being concentrated in a few hands. The company had a selling and production orientation derived from its history in merchanting. Today this culture is changing. Present management wish to preserve the best features of the old culture, add a Total Quality orientation, and in the process create an organisation which is recognised to be:

- a responsible member of the community, providing continuity of employment in a safe workplace and respecting the environment, both locally and globally
- committed for the long-term to its customers and markets
- committed to the principle of establishing a partnership with customers and suppliers alike

- a provider of the highest quality of products and services
- innovative and a technological leader in its product fields

2.3 Company Structure

Don & Low have four manufacturing units and recent re-organisation of these factories has taken place in an effort to allow each unit to concentrate on manufacturing one type of product:

- Newfordpark, Forfar: polypropylene tape extrusion
- Canmore Works, Forfar: weaving of secondary backing
- St James Works, Forfar: weaving of primary backing
- Wallace, Perth: weaving of industrial products and tufted carpet backing

In addition, there is a warehousing and distribution centre, based in Forfar, and the Head Office is located at St James Works, Forfar.

The extrusion and weaving factories, are run 24 hours a day, seven days a week, fifty weeks a year - on an innovative seven-day, five-shift operation. Introduced to the skilled workforce in 1986, this shift pattern increased production and has become a model for manufacturing industry in the UK. Today, all of Don & Low's production operates under BS5750 (ISO 9000). Every stage of manufacture sees rigorous quality control and inspection.(Don & Low)[5]

In an effort to produce better quality products more efficiently, Don & Low were one of the first British polypropylene weaving and extrusion companies to introduce a comprehensive computer monitoring system. This links all the factories and covers every aspect of their operations, extending from the intake of raw material on to production processes, stockholding and sales.

2.4 Products

Don & Low products range from industrial yarns to geotextiles, from woven primary and secondary carpet backings to non-woven fabrics for the automotive, packaging and finishing industries.

2.4.1 Tufted Carpet Backings

Forming a major part of the company's business, these turfted carpet backings (TCBs) are manufactured from polypropylene tapes using traditional weaving methods. Apart from plain woven backings, additional processes such as needling - punching loose nylon fibre into the cloth and calendering - bonding layers of fibre onto cloth by heat and pressure, produce durable, high quality fabrics known under the trade names, Keybond and Primebond. At Europe's largest Dref open-end spinning plant, Don & Low produce the polypropylene yarn for their range of Lobac secondary backings - the modern equivalent of jute carpet backing.

2.4.2 Industrial Yarns

Whilst the bulk of Don & Low's polypropylene extrusion produces tape for TCB weaving, the company has also made considerable investment in extrusion lines dedicated to the production of slit film yarns. These high performance tapes and yarns are supplied either twisted or flat, with both extrusion and twisting processes under computer control. Continuously scanned to maintain consistency and quality, they are used in products as varied as curtain header tapes and artificial grass. A major application is in woven carpet weft yarn and Don & Low are established as one of the UK's main suppliers in this market.

Physical properties such as thermal stability and high tenssile strength also mean that these tapes and yarns are ideal for use in webbings, flexible container components and geotextile fabrics.

2.4.3 *Geotextiles*

In recent years, the use of polypropylene geotextiles in the construction and civil engineering industries has become widely accepted. Don & Low's range of Lotrak woven geotextiles has proved to be a leader in this field.

Supplied for a variety of building and civil engineering purposes, these permeable, synthetic membranes are used to strengthen foundations and stabilise ground in construction work of all kinds. For roads, railways and airfields, as well as in the increasingly important field of soil and coastal erosion. Their permeability makes them ideal for use in drainage situations, protecting and extending the life of open and buried rubble drains.

2.4.4 *Industrial Fabrics*

Don & Low also manufacture a wide range of general industrial fabrics for a multiplicity of products and end uses. The main production in this sector remains in polypropylene textiles. Servicing the established floorcovering and carpet markets, Don & Low supply woven underlays and base fabrics for carpet tiles. A similar range of materials is available for the furnishings and upholstery manufacturers.

The Industrial Fabrics Division also manufactures a variety of high performance textiles which have uses ranging from flexible intermediate bulk container components to specialist webbings for the transportation and packaging industries.

2.4.5 Nonwovens

Don & Low Nonwovens complement the weaving operations of Don & Low Ltd. This company uses the latest nonwoven polypropylene extrusion and spinning technology and produces a range of innovatory lightweight, durable and washable fabrics and textiles. Under the brand name Daltex, these products are used in disposable protective clothing, roofing felt, furnishings and consumer packaging.

2.5 Health, Safety & Environment Policy

Don & Low's Health, Safety & Environment Policy states :

"It is the policy of the Don & Low Group to give the greatest importance to all aspects of safety, health and the environment. People are our most important asset. We, therefore, place the highest priority upon the health and safety of our employees, our customers, contractors and members of the public who come into contact with our business operations."

In the belief that all accidents are preventable, the Group intends to eliminate all work related injuries and illnesses and to achieve the highest standards with regard to protection of the environment. The policy is as relevant to staff in offices and travelling on company business as it is to those employed in production.

"All employees and contractors should consider it their basic duty to exercise personal responsibility and co-operate in preventing harm to themselves and others. The contribution of every employee and of all contractors to improving health and safety performance will be valued as essential to the success of the business".

The Chief Executive is responsible for providing the necessary resources to enable the Group to achieve the high standards of safety and health outlined in the Policy. Line Managers and employees have responsibility for implementing specific aspects of the safety policy.

The Don & Low Group recognises that safety is a line management responsibility which ranks equally with the other business aims and objectives. The Company believes that these aims can best be achieved by adopting a "No-Blame" culture to foster strong communications between management and employees. The Company will ensure that safety is the first agenda item at all management meetings.

The Group will respond positively and thoroughly to the requirements of Legislation, Regulations and Codes of Practice related to health, safety and environment. In addition, the Company will promote the development of the various audit programmes, health education and other health and safety promotion.

The Company believes that high standards of safety can only be sustained where employees are fully trained and are aware of the intrinsic hazards of their work. A comprehensive induction programme coupled with on and off the job training as appropriate will be provided by the Company for all employees.

Each location will have a safety committee chaired by the location manager which will meet on a regular basis at least bi-monthly. Safety committees will consist of delegates nominated from within the workforce according to its constitution. The role of safety committees is non-executive.

Each safety committee chairperson will be an automotic member of the Chief Executive's Safety Forum which will meet on a quarterly basis. Its function will be to review the Group's safety performance and to formulate safety, health and environmental policy.

The company will contract the services of BUPA Occupational Health to provide an effective efficient occupational health service and to advise on health issues.

2.6 Environmental Management System

Don & Low operate an environmental management system which follows the principles of BS7750. (Don & Low)[5] This environmental policy is relevant to their activities, should be understood and maintained at all levels, and is publicly available. Don & Low have a commitment to continual improvement in their environmental management and is willing to set and publish their objectives.

Their environmental system is clearly defined with documented responsibilities, authority and inter-relations. They are committed to providing adequate resources and trained personnel, management representatives and qualified personnel to ensure the effective operation of the system.

Regarding environmental effects, the system records all legislative, regulatory and policy requirements. Communication and procedures have been set up for examining and assessing environmental effects.

Consideration is given to normal operating conditions, abnormal operating conditions, incidents, accidents, emergencies, past, present and future activities. A register of significant effects is maintained covering:

(a) *emissions to the atmosphere*

(b) *discharge to water*

(c) *use of land, water, fuel and energy*

(d) *noise, odour, dust, vibration*

(e) *visual impact*

Verification, measurement and testing of environmental effects are carried out to verify compliance with requirements. Specified procedures are in place and acceptance criteria are established. This verification, measurement and testing is documented as follows :-

(a) *determine the cause*

(b) *draw up a plan of action*

(c) *initiate preventative actions*

(d) *apply controls*

(e) *record procedural changes*

CHAPTER 3

NOISE, PRINCIPLES AND HEALTH EFFECTS

3.1 Basic Principles and Definitions

It has been known for hundreds of years that workers in noisy industries can suffer permanent hearing damage, though it is only over the last two decades that generally accepted procedures for assessing industrial exposure and risk have been developed. (Health & Safety Commission, 1987)[87].

Noise, a prototypical environmental stressor, has clear health effects in causing hearing loss but other health effects are less evident with well documented associations between noise exposure and changes in perf--ormance, sleep disturbance and emotional reactions such as annoyance. Noise is often defined as "unwanted sound", perceived as harmful or unpleasant. (Stephen A Stansfield, 1992)[7].

Noise is a term used to identify unwanted sound, including random sounds and sound generated as a by-product of other activities, including transportation and industrial operations. Intrusive sound, including speech and music unwelcome to the recipient are also considered noise. Thus, the distinction between noise and sound can be subjective, and the two terms are often used interchangably (Wilson,C. E., 1989)[8].

The human ear is responsive to frequencies ranging from 20 to 20,000 Hz for normal sound intensity levels. Frequencies above this range are no longer audible to the human ear, and so are described as ultrasonic (WHO, 1972)[9]. Though there exists a great deal of individual variation in ability to perceive very low or very high frequency sounds (Nadakavukren, A., 1990)[10].

Sounds normally heard are made up of numbers of different frequencies. The possible range of frequencies of sound is large. In the usual notation of numbers of cycles per second, the whole range or spectrum of frequen--cies of sound is roughly classified into three bands of frequencies by the criterion of audibility to the human sense of hearing.

3.2 Sound Power Level Lw_A

The sound power level Lw_A is obtained by applying the weighting A to the sound power level Lw.

The sound power level Lw, expressed in dB, of a sound source is defined by

$$Lw = 10 \log_{10} \left\{ \frac{W}{W_o} \right\}$$

where:

W is the total sound power generated by the sound source expressed in watts;

W_o is the reference sound power, equal to 10^{-12} W.

The value Lw_A of the A-weighted sound power level, expressed in dB, is obtained by applying the weighting A to the measuring system.

The range of values of sound pressure, and even more so, of sound intensity normally encountered is inconveniently large for normal arithmeti--cal expression.

3.3 Sound Intensity

The sound intensity (*I*) in watts per square metre (W/m^2) is the quantity of sound energy passing through unit area per unit time, and is relevant only when related to a particular location under stated conditions. It is the sound intensity at the ear which has been shown to govern the degree of hearing loss, therefore measurements are made at a defined distance (*r*) from the source, usually at the ear of any exposed individual.

The lowest intensity of sound that is detectable by the human ear is 10^{-12} W/m^2 and is the established 'threshold of hearing'. By contrast, the highest intensity that the ear can hear without feeling pain is between 1 W/m^2 and 10 W/m^2, therefore the 'threshold of pain' lies in the this region.(Waldron H.A. 1989)[2]

The ear is frequency sensitive and all frequencies are given different values of dB for 0 dB (hearing threshold level). Sounds of different frequency, at a constant sound pressure level (SPL), do not evoke equal loudness sensations. This phenomenon is neither linear with amplitude nor with frequency and "loudness level" is measured in units of the phon. The sound is compared again to a standard reference signal of 1000 Hz. The reference sound pressure level at 1kHz is 0.0002 microbar=20 Un /N_2.

A measuring instrument can make allowance for this phenomenon by the use of a series of frequency weighting networks. Four of these weightings are standardised. The A-weighting, which is now used almost exclu- -sively was originally designed to follow the response of the human ear at low sound levels, to a first approximation. The B- and C- weightings were originally intended to be used at higher sound levels and their response was designed to follow the approximate response of the ear at levels between 55 and 85 dB and above 85 dB, respectively. The fourth weighting network, D-, is used specifically for aircraft noise measurement. See (Figure 3.1).

FIGURE 3.1 THE INTERNATIONALLY STANDARDIZED WEGHTING CURVES FOR SOUND LEVEL METERS

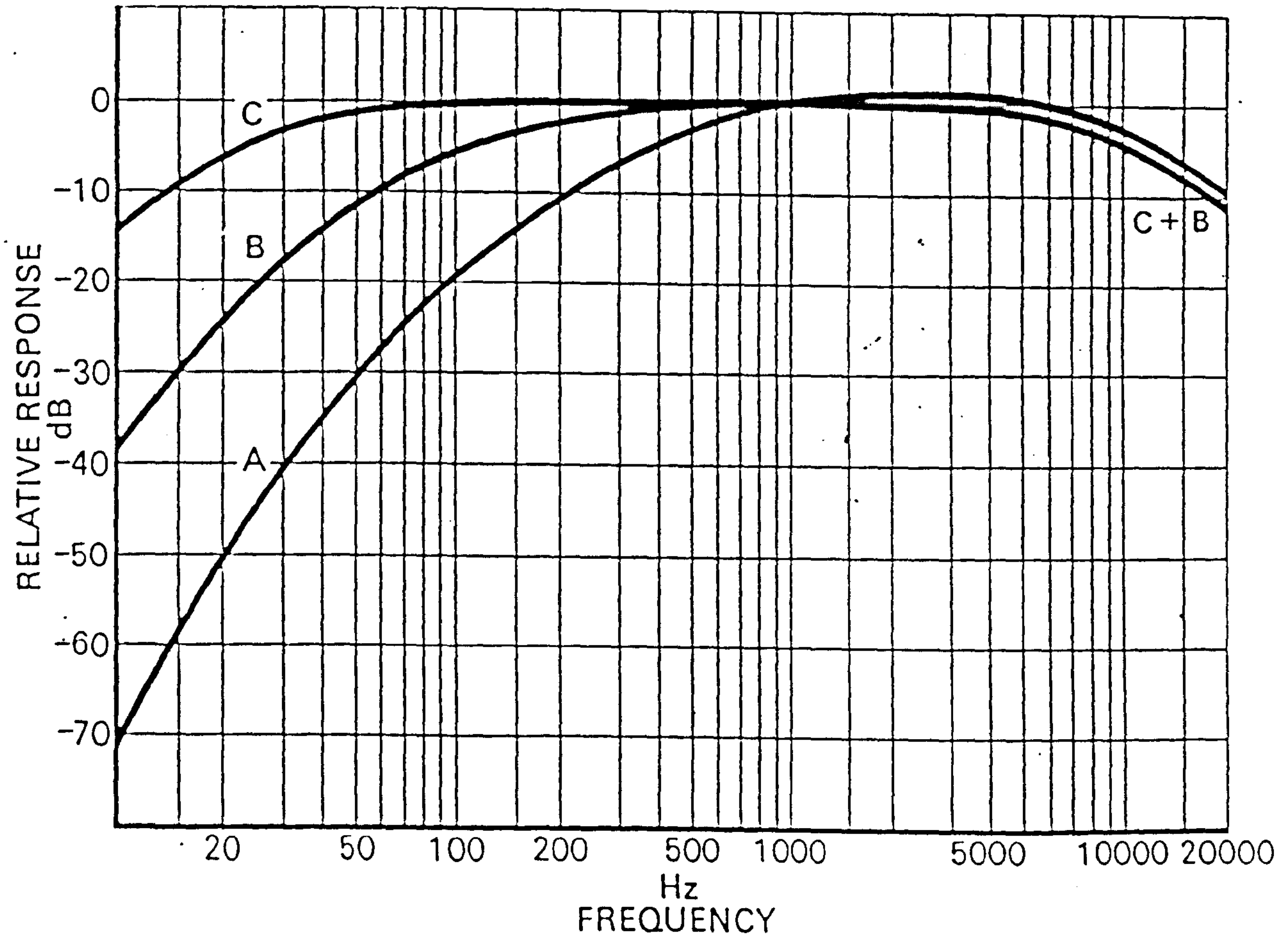
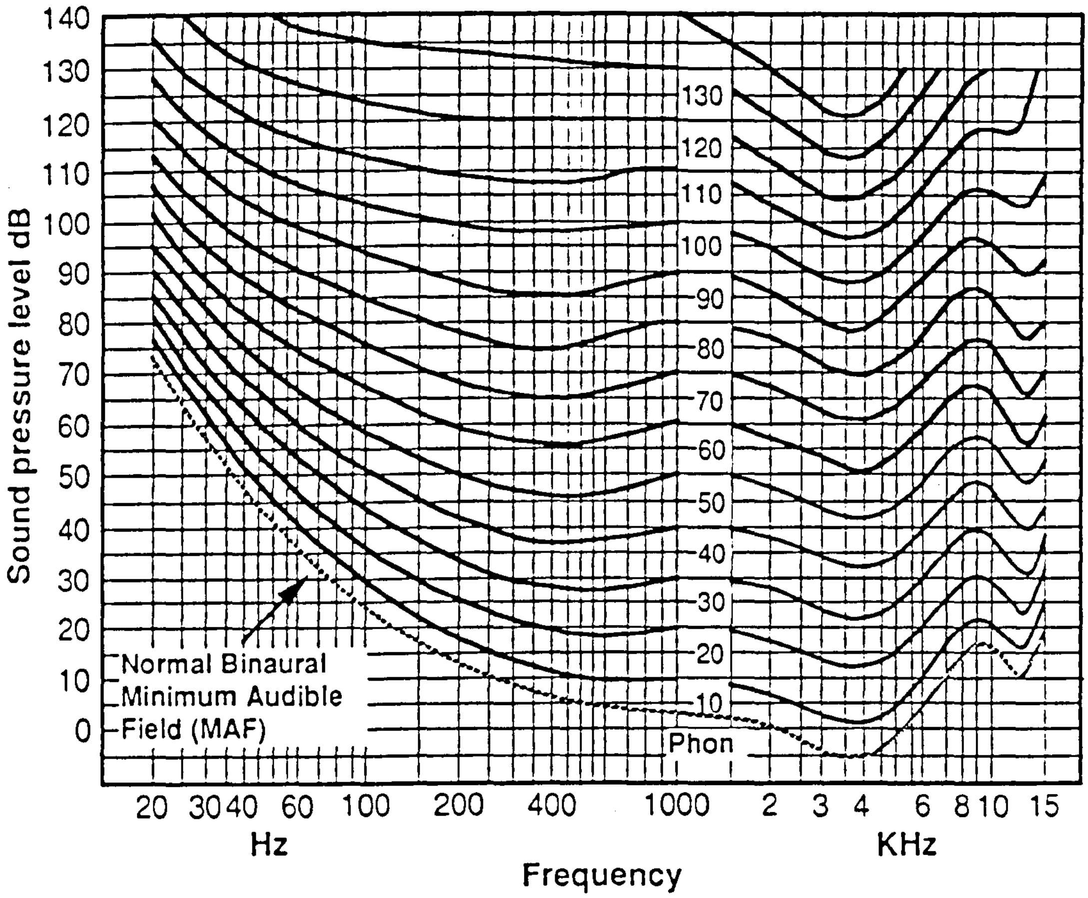


FIGURE 3.2 NORMAL EQUAL-LOUDNESS CONTOURS FOR PURE TONES. THEY APPLY TO OTOLOGICALLY NORMAL PEOPLE AGED 18-25 YEARS WHEN LISTENING BINAURALLY TO SOUND COMING FROM DIRECTLY AHEAD



It frequently happens that a noise has to be investigated in detail from the point of view of mechanical considerations, annoyance or potential damage to hearing and in such cases examination of the distribution of intensity in the frequency spectrum must be undertaken. The procedure for measurement of sound pressure at different parts of the frequency spectrum is known as octave band analysis. This procedure involves a system of filters which will pass only certain bands of frequencies. The bands are contiguous and the centre frequencies by which the octave bands are identified extend upwards and downwards from 1000 Hz. The details of the preferred frequency bands are seen in (Figure 3.2). The SPL of each band is measured and the sound can thus be described in numerical values of SPL in each of the octave bands.

3.4 Measurement of Sound

Having gained some impression of the physical nature of sound in a qualitative way, it is necessary to turn to the essential step of expressing sound quantitatively. The measurement and quantitative handling of sound is the essence of the science of acoustics.

Any audible sound is treated as a noise. Where persons are in a noisy environment the noise should be measured in the working areas they occupy throughout the day, using a procedure which obviates or minimises the effects of reflections of sound from the person, i.e. if the noise is generated inside a headset or helmet worn by the person, the level measured inside the device may be adjusted to obtain an equivalent environmental sound pressure which would cause the same level of sound to be received by the ear - the adjusted level will generally be lower than the measured level.

There is a wide selection of equipment for the measurement of noise in the workplace, ranging from the single general-purpose-type sound level meter for the determination of overall noise levels to the more accurate and versatile precision sound level meters which may be capable of measuring impulse noise and/or integrating sound pressure levels over a period ranging from a few seconds to a full day.

The peak pressure must be measured without frequency weighting. Most equipment is unsuitable for accurate measurement of this quantity, but a very rough assessment of whether more sophisticated measure -ments are needed can be made with a simple sound level meter set to "F" (fast) response. If the reading exceeds 125 dB it should be assumed that a more accurate measurement ought to be made.

The basic instrument for the objective measurement of sound is known as a sound level meter. It must comply with *BS6698 (IEC 804).* It consists of a microphone, an amplifier and some indicating device and is capable of measuring the value of equivalent continuous sound level over the whole day, or over sample periods. The microphone transforms sound pressure waves into electrical voltage fluctuations which are then amplified suffi- -ciently to actuate a meter, or alternatively a recorder of some kind. The most suitable microphone for sound level meters is the condenser micro -phone, which combines precision with stability and reliability. The current British Standard BS 5969 and its international counterpart IEC 651 are amalgamations of previous standards BS4197 for precision SLMs and BS 3489 for indsutrial grade instruments. Currently available under the new standards are types 0, 1, 2 and 3, where types 1 and 3 are roughly equivalent to precision and industrial grades respectively. Type 2, general-purpose, has been introduced to bridge the gap and type 0 is a new grade for laboratory grade instruments. (Hill, N., 1984)[11].

This device is best suited to measurement of continuous or intermittent periods of steady noise, e.g. in a weaving shed, but can also be used where fluctuations are not too great or irregular. If the noise is non-impulsive and fluctuates through a range of less than 8 dB(A), the average reading of the meters can be estimated by eye. These meters read over a small range, and this range is selected to suit the sound being measured, by the manual operation of an attenuator, so varying the effective amplification between microphone and meter (Wilson, C.E., 1989)[8].

In addition, a rectifier circuit is placed before the meter, which converts alternating currents in the amplifier into one-directional, or direct current (DC), suitable for actuating the meter, which is calibrated to read root mean square (RMS) pressure over a short interval of time.

A standard sound level meter, equipped with a "fast" and "slow" meter response is capable of directly measuring both a steady noise level and a slightly fluctuating noise level. However, the standard meter cannot be used to measure impulse noise because the rise time of even the "fast" meter response does not match that of the human ear and therefore the peak of such rapid transient noises is under-recorded. On the other hand some meters are equipped with an "impulse" time constant which enables the meter reading to increase very rapidly as the noise level increases.

Integrating sound level meters are used to determine the equivalent steady A-weighted noise level (Leq) corresponding to a time-varying noise situ- -ation over a known period. This is particularly useful when the noise environment under study can fluctuate strongly.

It is advised that these instruments be fully checked at least once every two years, and more often if there is any reason to suppose it has been damaged or has lost its calibration. This must be carried out by a properly equipped laboratory or by the instrument maker. In addition a simple calibration check should be made, each time the equipment is used, with a calibrator, which is electro acoustic or mechanical in nature. This emits a tone of known level and frequency and the reading on the SLM is adjusted if necessary. Frequency analysis allows us to look at the sound levels in each frequency band. This information is particularly useful when trying to locate the cause of a noise problem (Wilson, E.C., 1989)[8].

The personal noise dosimeter, an instrument small enough to attach to an individual during the working day to ascertain noise exposure, is a particular type of integrating sound level meter.
It is extremely useful in determining exposure for jobs where the worker moves around between areas of differing noise level. The microphone usually has to be located very close to the person's body as reflections may affect the reliability of the result. The dosimeters are calibrated so that a reading of 100% is given after an Leq of 90 dB(A) has been reached over 8 hours (Ellison, J. 1987)[12].

3.5 Noise Induced Hearing Loss (NIHL)

3.5.1 Historical Introduction

It has been suggested that hearing loss due to occupational exposure to noise dates at least from the "Bronze Age". The discovery of metals, first bronze and later iron, allowed their extensive use in industry involving hammering and forging to produce useful tools. Thus occasioned the first situation in which human hearing was at risk from occupational noise. As the industrial revolution expanded, accom panied with the mechanisation of factories after the second world war, noise pollution increased.

Economies in size were made at the expense of a large increase in sound levels. Machinery and equipment in a number of industries are associated with production of noise, as in refineries, construction and transportation. Military machinery also became more devastating and deafening (John and John, 1979)[13].

Nils Skargge (over 200 years ago) wrote a thesis on the occupational deafness in coppersmiths and blacksmiths, and Fosborke in 1831 gave an accurate description of noise-induced deafness. (John and John, 1979)[13].

For hundreds of years, many people have paid a high price for industrial noise. Furthermore, levels of noise which produce hearing loss can cause annoyance and interfere with concentration and communications in the workplace, whereas in the community, noise from any source (not necessarily industrial), can cause annoyance and loss of sleep (H.A. Waldron, 1989)[2] (Table 3.1).

TABLE 3.1 (Levels of Noise and Risks)

(dB)	Risks
150	Instanteous damage
140	
130	Threshold of pain
120	
110	
100	
90	Permanent hearing loss
80	Discomfort
70	Annoyance
60	
50	
40	
30	
20	
10	
0	Threshold of hearing

John and John (1979)[13] gave a historical account of the audiometric character and changes associated with exposure to noise :

- The site and nature of lesion were first described by Habermann (1890).
- Bunch (1937) published probably the first audiometric data demonstrating the typical high frequency loss acquired by those exposed to noise.
- Fowler (1939) observed dips at 4 kHz.
- Dickson, Ewing and Littler (1939) described the aviators notch at 4 kHz in pilots of piston-engined aircraft.

3.5.2 *Definitions of Occupational Noise Induced Hearing Loss:*

Occupational NIHL, as opposed to occupational acoustic trauma, is a slowly developing hearing loss over a long period (several years) as the result of exposure to to continuous or intermittent loud noise. Occupational acoustic trauma is a sudden change in hearing as a result of a single exposure to a sudden burst of sound, such as an explosive blast. The diagnosis of HIHL is made clinically by a physician and should include a study of the noise exposure histroy (American Occupational Medicine Association, 1987)[15].

3.5.3 *The principle characteristics of occupation NIHL:*

In 1989, a committee of the ACOM, now the American College of Occupa tional and Environmental Medicine, published a position statement on NIHL,(Dobie, R.A, 1995)[14] which is reproduced below.

1. *It is always sensorineural affecting the hair cells in the inner ear.*
2. *It is almost always bilateral. audiometric patterns are usually similar bilaterally.*
3. *It almost never produces a profound hearing loss. Usually, low-frequency limits are about 40dB and high-frequnecy limits about 75 dB.*
4. *Once the exposure to noise is discontinued, there is no significant further progression of hearing loss as a result of the noise exposure.*
5. *Previous NIHL does not make te ear more sensitive to future noise exposure. As the hearing threshold increases, the rate of loss decreases.*
6. *The earliest damage to the inner ears reflectss a loss at 3000, 4000, and 6000Hz. There is always far more loss at 3000, 4000, and 6000 Hz than at 500, 1000, and 2000 Hz. The greatest loss usually occurs at 4000 Hz. Ther higher and lower frequencies take longer to be affected than the 3000 to 6000 Hz range.*

7. *Given stable exposure condidtions, losses at 3000, 4000, and 6000 Hz will usually reach a maximal level in about 10 to 15 years.*
8. *Continuous noise exposure over the years is more damaging than interrupted exposure to noise, which permits the ear to have a rest periods.*

The ACOM statement is most useful to remind physicians that the diagnosis of NIHL should not be made unless there is a history of potentially hazardous noise exposure. Many "noisy" jobs are not hazardous to hearing. One may quibble aobut exceptions to some of the stated characteristics, but far fewer diagnostic errors would occur if the ACOM criteria were adhered to universally.

3.6 Size of the Occupational Noise Problem

As mentioned previously the number of workers occupationally exposed to noise has continually increased since the industrial revolution. In addition to the heavy industries traditionally associated with this problem, construction workers, textile workers, truck drivers and pilots are included. In Great Britain, it was estimated that about 1.7 million employees in manufacturing industry alone were shown to be exposed to hazardous levels of industrial noise (Health and Safety Commission, 1987)[6].

Concern about industrial noise problems has continued to grow during the past two decades. As a result of increasing levels of noise exposure and greater understanding of the effects of noise, legislation to limit noise exposure has been recently enacted with further legislation impending (Al Nassar, Al-Bestar, Nowair,1991)[16].

The WHO reported that the occupational limit adopted by a number of countries for noise is 85dB. The allowable noise does varies slightly between different countries but it is usually between 85 or 90 dB(A) and is referred to as the criterion noise dose, (J. JEYARATNAM, 1992)[17].

The WHO report indicated that hearing loss occurs afer prolonged expo sure to intensive noise above 85dB. Dobie[9] agrees that exposures to noise level between 85 to 90 dB(A) will cause substantial noise-induced hearing loss in at least 5-10% of exposed workers (WHO, 1986)[18].

3.7 *Age and Noise Exposure*

Two components are responsible for decline of hearing threshold levels as age advances; a physiological factor termed presbyacusis, and an environmental factor termed sociocusis which is the hearing loss due to non-occupational exposure to noise. Since the contribution of each factor to hearing loss cannot be given in isolation, the effects of both presbyacusis and sociocusis are combined together and called age effect (Royster, 1980)[19].

The inter-relationship between presbyacusis and noise-induced shifts is not fully understood. It is not known whether the effect of age and noise are additive, or synergistic.

Ageing and its effect upon hearing remains a major problem. Although mass data can identify the changes attributed to age, individual differences make it extremely difficult to determine whether audiometric changes are the result of ageing, noise exposure, or some other factor. Also, while it is known that there appears to be an inverse relationship between TTS (Temporary Treshold Shift) and permanent threshold shift, the proof that greater TTS is associated with noise susceptibility remains inconclusive (Catlin, 1986)[20]

Robinson and Shipton (1977)[21], suggested a formula for age correction in estimating the value of noise induced hearing loss, based on experimental data, but not to be considered presbyacutic data for general application :-

$F = C (N - 20)^2$ where N is the age in years, and the value of C is obtained from Table 3.2.

TABLE 3.2 (A Formula For Age Correction)

F (KHz)	0.5	1	2	3	4	6
C	0.004	0.0043	0.006	0.008	0.012	0.014

The age correction factor "F" can be used for those aged 20 - 70 years (since the value below 20 years is 0), for the six audiometric frequencies 0.5, 1, 2, 3, 4 and 6 kHz, and for the frequency combinations of 0.5, 1 and 2 kHz; 1, 2, and 3 kHz, 1, 2, and 4 kHz and 3, 4, and 6 kHz.

3.8 *Effect of Continuous Noise Exposure*

Sound, manifest as environmental noise, has temporary or permanent effect of noise-induced hearing loss. Exposure to higher intensity and certain types of noise may increase this risk but there is also evidence of individual susceptibility (Kryter, 1985)[22].

The Taylor, Pearson , Mair and Burns (1965)[23] retrospective study of noise and hearing in the Jute weaving industry of Dundee, Scotland, appeared in the mid 1960's. The attractive features of this investigation were that the population was extremely stable, some employees having worked at the same loom for up to 50 years, and that the widesband continuous noise has remained virtually unmodified for about 70 years (the looms were installed in 1892). In addition the weaving population was predominatly female, and not subjected to other types of high-frequency noise. The data for four groups were compared; employees in the jute industry not exposed to noise and aged 18-25 years; school teachers aged 18-25 years; weavers aged 18-25 years with various durations of exposure to a known weaving noise, and retired weavers with various durations of exposure to the known weaving noise, followed by various durations of retirement. The first two gropus were used as controls. Only those weavers were tested for whom the noise level was 99-102 dB overall SPL. The greatest change in the threshold, about 40dB (age corrected), occured at 4KHz within the first 10-15 years. There was an additional loss of only 10dB for a further exposure of 40 years. The shift at 2 KHz reached a maximum of 40dB only after 40 years of exposure, and the threshold at 1 KHz shifted gradually over the period of 50 years to about 20dB. Thus while the hearing loss at the higher frequencies had reached an asymptote after a relatively short period of exposure, deterioration continued to progress gradually into the lower frequencies with time.

3.9 Properties of decibels

Decibels cannot be added or subtracted arithmetically. To combine sound level, dBs must be expressed in logarithmic form, so that intensity values can be calculated. after adding or subtacting intensities, the combined value can be converted back to dBs, which should be corrected to the nearest whole number.

TABLE 3.3 Rule of thumb for adding or subtracting decibels

Addition of two values

For a difference of:	The higher value is increased by:
0 or 1 dB	3 dB
2 or 3 dB	2 dB
4 to 9 dB	1 dB
10dB or more	0 dB

Subtraction of two values

For a difference of:	The higher value is reduced by:
10dB or more	0 dB
6 to 9 dB	1 dB
5 or 4 dB	2 dB
3 dB	3 or 4 dB
2 dB	4 or 5 dB
1 dB	5 to 10 dB
0 dB	10 dB or more

When adding mre than two levels, group in pairs and add successive totals as in example below:

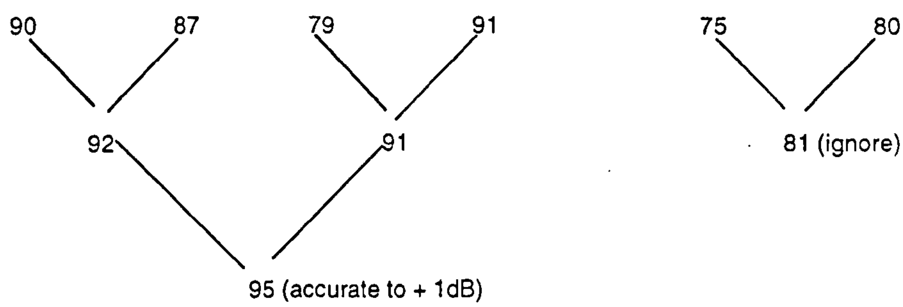
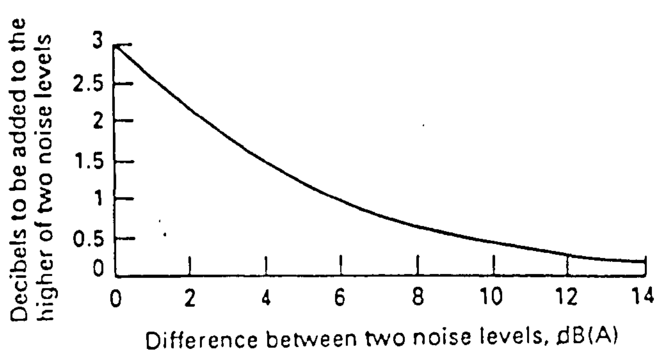


FIGURE 3.3 Noise Level Addition Chart (courtesy of Bruel and Djaer)



In practice, there is no need to use this cumbersome method of calculation it is easy to remember a simple 'rule of thumb' as outlined in Table (3.3), which is derived from (Figure 3.3). This information is useful for estimating the noise level from one of a number of noise sources where some or all of the others cannot be switched off.

A noise is continuous if, once initiated, it continues for a prolonged period of time. Since, in some respects, our scaling of time is relevant to the event being studied: this definition is not very precise but for an industrial exposure situation we might consider an 8 hour period as representing a continuous exposure (Waldron, H.A, 1989)[2].

Recent studies into the effect of continuous noise exposure include a survey carried out on orthopaedic staff to determine the risk posed by powered orthopaedic instruments. The noise levels from a number of air-powered and electric tools were measured and analysed and found to exceed the recommended levels. The predicted daily personal noise exposure (LEP,d) was calculated. The Health and Safety Commission's recommendation defines the first level of noise exposure deemed unsafe to be a daily personal noise exposure of 85dB. There was audiographic evidence which was highly suggestive of noise-induced hearing loss in 11 of the 22 subjects See Table (3.4).

TABLE 3.4 Audiographic Results for Medical Staff

Subjects with a minimum of 5 years recent exposure	Number	Mean (yr)		Subjective Deafness	NIHL
		Age	Exposure		
Consultants	16	47	22	4	8
Senior Registrars	4	36	5.7	0	0
Theatre Nurses	2	41	13	1	0
Plaster Technicians	5	46	22	3	3

The noise-induced hearing loss detected in this study showed a peak loss at 6000Hz, while the common pattern of industrial "factory noise" damage is usually at 4000 Hz. The mean loss, corrected for age and sex, at 6000 Hz for both ears was 12.3 dB (0 to 40) and for the worst affected ear 15.9 dB (7 to 40). (Willet, 1991)[24].

Another recent study was conducted on workers exposed to continuous noise in a factory to assess the pattern and extent of noise-induced hearing loss. The weighted sound pressure levels in dB and the average noise dose were measured in the study area. The workers were examined otologically and audiometric evaluations were performed on the exposed workers and a group of controls. The overall noise level measurement was 93.8 dB(A) in the electric power station area and 86.4 dB(A) in the milling department with the type of noise described as "continuous steady state". There was a statistically significant difference in the mean hearing threshold level between the exposed workers and their controls in all the tested frequencies for both ears. The highest hearing threshold level value for the exposed workers was at 6000 Hz for both ears. There was an inconsistent pattern between hearing impairment and the duration of exposure but an increase in the mean hearing threshold level was evident at all frequencies in workers with a duration of exposure between 10 and 15 years. Hearing impairment was present in 55% of workers (Nassar, Al-Bestar, Nowair, 1991)[16].

In a hearing survey, on 76 physical plant employees of a major teaching hospital who were exposed to high intensity levels of noise in certain work locations, followed by a quiet period of at least 14 hrs, pure-tone thresholds were obtained from them for the octave frequencies (250 through 8000 Hz). A total of 53 subjects demonstrated some degree of sensorineural hearing loss. (Dempsey, 1984)[25].

"A seventy year old man exposed to occupational noise had 10 to 15dB poorer hearing in the high frequency range than a non-exposed man"(Svanborg & Dederson, 1990)[26]

The duration of exposure also affects the shape of the audiogram. This is largely because the rate of deterioration of hearing loss varies at any given frequency. For example, at 4 kHz, hearing deteriorates rapidly in the first 10-15 years but is larely unchanged thereafter, whereas, at 2kHz, the most rapid change in threshold occurs after 20-40 years of exposure (J. Irwin, 1994)[27].

It can be concluded that since the end of World War II the relationship of hearing loss to noise exposure has been quite widely studied, but the data directly of use for the prediction of the damaging effect of different noise levels, are not very numerous and the complexities of the situation are such that there are yet many uncertainties.

The characteristics of the condition is that as a result of work in a noisy situation, deterioration of hearing occurs at a rate determined mainly by the level of the exposure, but usually it is initially unnoticed.

Temporary dullness of hearing after exposure to noise at work, with perhaps some noise in the ears (tinnitus) are the usual signs that damage is being done to hearing.

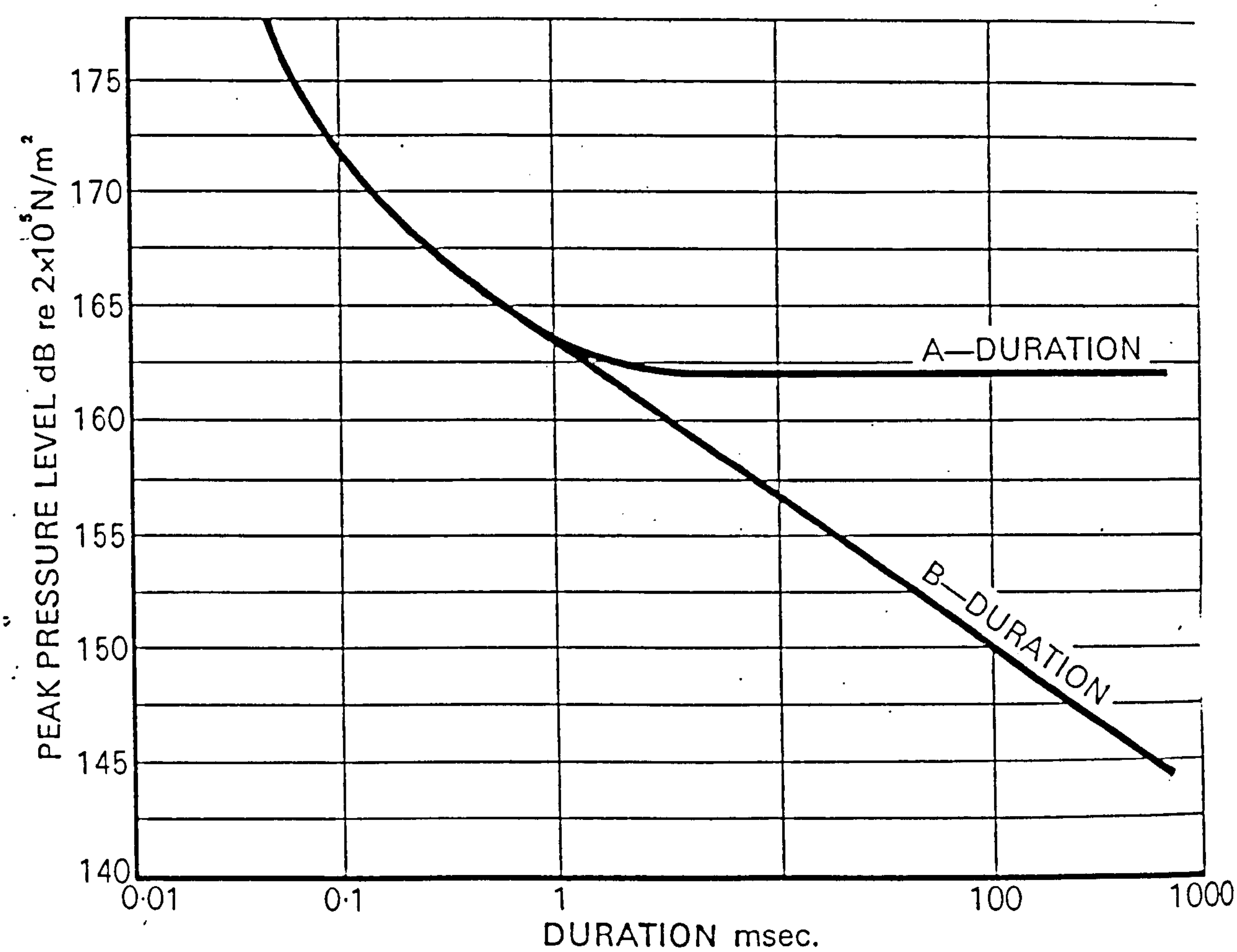
3.10 Impact and Impulse Noise

An important feature of many sources of noise in a practical situation is the time characteristic of the noise. A noise may be discontinuous, and the intermissions may be of a regular or irregular nature. For example, road traffic noise will be affected by density and periodicity of the passage of vehicles or the repeated operation of an industrial process may affect greatly the seriousness of a noise disturbance. The nature of noise may change with time, adding further complication.

Where a sound is totally discontinuous as for example in hammering, stamping or forging operations this is classed as impact noise. Here the sound energy is restricted to a very short interval of time, and the repetition rate may be very variable. The repetition of impact noise is of some significance in assessing its potentially harmful effect on hearing.

Impulsive noise exposures can, in general, be more hazardous than continuous noise exposures. Part of the reason for this is that, subjectively, we tend to underestimate the potential of an impulse for causing trauma because its transient nature makes it seem quieter than it truly is. (Figure 3.4) indicates the damage risk specification for impulse noise (Burns, 1968)[28].

FIGURE 3.4 DAMAGE RISK SPECIFICATION FOR IMPULSE NOISE



A study was conducted in the drop-forge industry of 11 Swiss factories into the effect of long-term exposure to impact noise on hearing; the experimental data showed a significant increase of hearing loss with higher noise level and longer exposure (Guberan, 1971)[29].

Exposure need not be long-term to damage hearing if the sound frequency is high. A single shotgun blast registering 140 dB can permanently affect hearing. Any noise that forces one to shout to be heard poses a danger to auditory capability (Allen, 1990)[30].

3.11 *TTS versus PTS*

A person with NIHL (noise induced hearing loss) will probably suffer from a difficulty in hearing and understanding of ordinary speech. The profile of NIHL is usually symmetrical in both ears and when caused by habitual exposure to moderate levels of noise, consists of two stages. The first phase involves a decreased hearing acuity immediately after exposure that lasts from minutes to hours thereafter and is referred to as temporary threshold shift (TTS). After exposure, if the threshold shift does not recover, a second stage of cochlear damage has occurred which is called permanent threshold shift (PTS). This is irreversible (Burns, 1968)[28].

It is estimated that at least 20 million Americans are being exposed daily to levels of noise which are permanently damaging to their ability to hear. Most people are familiar with the temporary deafness and ringing in the ears which occurs after sudden exposure to a very loud noise such as a firecracker exploding close to one's head. This type of partial hearing loss generally lasts a few hours at the most and is referred to as temporary threshold shift (TTS). However, it is not widely recognised that regular exposure to levels of noise commonly encountered in everyday life can, over a period of time, result in permanent hearing loss (Nadakavukaren, 1990)[10].

Noise may affect hearing in ways that are broadly divisible into three categories; temporary threshold shift, permanent threshold shift and accoustic trauma.

In combination with the fact that the ear is most sensitive around the 1KHz to 5kHz region, TTS is therefore most common around the 4kHz region, even though the exposure is to noise of much lower frequency (Irwin, J, 1994)[27].

Temporary threshold shift is a short term effect which may follow an exposure to noise, and as its name indicates, the elevation of the hearing level is reversible. The effects of a particular noise exposure in terms of temporary threshold shift are dependent on individual susceptibility. The term persistent threshold shift is used to denote the threshold shift remaining after at least 40 hours. The word permanent is reserved for conditions which may reasonably be supposed to have no possibility of further recovery.

3.12 Acoustic Trauma

Acoustic Trauma occurs in the wedge-shaped organ of Corti in the cochlea of the ear. This structure, resting on the basilar membrane, has three outer rows and one inner row of hair cells with the tectorial membrane suspended above them. The hair cells have stereocilia projecting toward the tectorial membrane. The energy of sound causes vibration of these cilia; this vibration is then coded into nerve inpulses in the acoustic nerve located beneath the hair cells. These hair cells are quite susceptible to the trauma of loud noise. Noise induced anatomic changes are seen in the cell bodies, which swell and eventually are destroyed. Once destroyed, they are lost forever, leading to loss of function. It is known that sound frequencies in the 1,000 to 4,000 range are transmitted best to the cochlea, which partially explains the typcial finding of greatest loss of hearing acuity at 4,000 Hz in acoustic trauma (Alexiou, Gladfelter, Saraceno, 1986)[31].

Exposure to intense sounds (greater than 140dB(A)) of short duration, such as gunfire or an explosion, can produce immediate, severe and permanent hearing loss, which is termed accoustic trauma. Such high intensity sound waves can disrupt virtually any structure in the middle or inner ear (Patrick E Brookhouse, 1994)[32].

3.13 Susceptibility to Noise

Individual variations in the extent of hearing loss occur for other reasons. Some people seem to have 'hardy' ears while some ears are 'tender', with marked hearing loss after minimal exposure to noise. Noise also acts synergistically with other ototoxic agents such as some drugs and vibration (J Irwin, 1994)[27].

The degree to which noise affects people depends on a number of factors, e.g.frequency, loudness, time of day, unexpectedness, un certainty of direction and unfamiliarity, irregularity and duration, necessity, general state of health and level of background noise. The effects of noise on people are various and often interrelated and will vary from person to person. Noise can cause stress, annoyance, behavioural change, hearing damage and physiological effects eg, hearing loss, high blood pressure etc.

A progression of noise induced hearing loss in a study of 350 workers in selected industries in Canada indicated that for any particular test frequency there was a considerable variability in the progression of hearing loss between individuals with the same noise exposure (Sharon, 1982)[33].

Susceptibility to noise induced hearing loss, similar to other human variables, shows big individual differences. Susceptibility to temporary threshold shift also differs, and differences are not uniform across the audible range of frequencies. Different individuals may be susceptible to low-pitch, medium-pitch or high-pitch noises. In general, women appear to be less susceptible to temporary threshold shifts from low frequency noise than are men, and the reverse to high frequency noises (Ronald Gallo, 1964)[34]. Hence, it is difficult to have a satisfactory measure to detect the individual susceptibility to noise-induced hearing loss in the very early stages of noise exposure.

3.14 Non-Auditory Effects of Noise

3.14.1 Physiological Effects

Hearing loss is the most obvious health threat posed by noise pollution, but it is by no means the only one.

Exposure to unwanted noise involuntarily induces stress, and stress can lead to a variety of physical ailments including an increase in heart rate, high blood pressure, elevated levels of blood cholesterol, ulcers, headaches and colitis (Nadakavukaren, 1990)[10].

Noise, a prototypical environmental stressor, has clear health effects in causing hearing loss but other health effects are less evident. Noise exposure may lead to minor emotional symptoms, changes in performance, sleep disturbance and emotional reactions such as annoyance (Stansfield, 1992)[33].

Noise mainly affects sleep and work performance and at the psychosocial level, it causes annoyance and irritation. Noise may lead to sleep disturbance or awakening. Sleep disturbance is frequently cited as the main cause of annoyance. Depth of sleep is affected by noise, and periods of very deep sleep may be reduced in length by impulsive noise of very short duration, whose intensity is 20 dB greater than that of the background noise. Above 70 dB, sound of no more than 300 milliseconds duration can interrupt deep sleep, and acoustic stimuli (white noise) of short duration cause EEG (Electro Encephelogram) changes. The probability that an individual will be awakened by pulse levels of 40 dB(A) is 5%, and this rises to 30% for pulse levels of 70 dB(A). Apparently, noise not only affects depth of sleep but also the type of sleep. When the mean sound level is low, an individual will take longer to go to sleep the greater the number of sound pulses. Noise induced deprivation of sleep in the early part of the night appears to be compensated by a longer period of deep sleep in the second half of the night (Kryter, 1970)[22] (Lang & Jansen, 1970)[35] (WHO, 1972)[9].

There is both objective and subjective evidence for sleep disturbance by noise. There are repeated findings of individual differences in susceptibility to sleep disturbance which include noise awakenings from sonic booms in soldiers scoring highly on neuroticism, worse sleep quality, more awakenings and more morning tiredness in noise sensitive students (Ohrstrom & Bjorkman, 1988)[36].

Physiological effects of noise include both specific auditory responses and non-specific non-auditory responses. For example, with regard to the cardiovascular system, noise may affect the rate of heart beat, but may either increase or decrease it, depending on the type of noise. Sudden changes in sound level or sound spectrum also modify heart rates. Noise generally causes heart output to decrease as well as an increase or fluctuations in arterial blood pressure and vasoconstriction of peripheral blood vessels (Kryter, 1970)[22].

The respiratory system reacts with apnoea to impulsive noise. Changes in breathing amplitude have been reported indicating a state of alarm.

Observed effects on the eye include pupillary dilation, narrowing of the visual field, decrease in the rate of colour perception and impairments of night vision (Lang & Jansen, 1970)[35]. Galvanic skin responses, which are a sign of activity in the reticular zone of the brain stem, reflect a decrease in the electrical resistance of the skin (Kryter, 1970)[32].

Generally speaking, the variety and variability of these non-specific responses show that they reflect the intensity of the reactions of the autonomic nervous system to noise intensity and band width. (WHO, 1972)[9]

3.14.2 Effects on Performance

Noisy surroundings can adversely affect work performance. Several years ago the National Institute for Occupational Safety and Health conservatively estimated that over 2.5 million U.S.

industrial workers were exposed to harmful levels of noise; aside from the health aspects of this exposure, noise hinders the performance of tasks requiring high levels of accuracy. Very loud sporadic noises seem to be the most disruptive, distorting perception, increasing the variability in work performance, disturbing concentration, and making it more difficult to remain alert.

The effects of working all day in a noisy environment frequently carry over into domestic life, making the worker more prone to aggravation and frustration when at home. (Nadakavukaren,1990)[10].

However, this is a very indefinable factor and depends upon the relationship between efficiency and the level of arousal of an individual. Any factor which affects the level of arousal will affect efficiency, i.e. motivation, sleep deprivation, heat, noise and other stress conditions.

If a sound affects the level of arousal, it will affect work performance in one way or another. Up to a certain level, sound can be beneficial by causing raised level of arousal and hence increased output. On the other hand, a further increase in the level of sound can reduce working efficiency, for example by interference with speech communication, mental concentration and personal comfort.

Poulton (1977)[37] has suggested that decrements in performance associated with noise results from the masking of auditory feedback and inner speech.

3.14.3 *Effects on Accidents*

There are very few studies which have dealt with the effects of noise on safety and efficiency in the workplace, yet several strong statements have been made about this topic. King (1947)[38] (addressing the National Safety Congress) stated that *"in certain circumstances, noise may actually be one of the direct causes of an accident".*

Similarly, Atherley and Purnell (1969)[39] stated that *"We are aware of no studies which show a consistent effect of noise on accident rate".* However, there have been studies of this topic and these will be briefly reviewed.

Kerr (1950)[40] reported a significant correlation (0.42) between the frequency of accidents and the noise levels of 53 departments in an electronics factory. Forty other factors were examined and noise produced the second highest correlation (after job mobility).

Cohen (1974)[41] showed that people who worked in high noise areas of a factory manufacturing boilers had more accidents than those in low noise areas in the same plant. The high noise group consisted of those exposed to levels of 95dB(A) or more, and 35% of this group had 15 or more injuries over the five year period investigated. In contract to this, only 5% of the low noise group (exposed to less than 80dB(A)) had a comparable injury rate. The number of accidents per worker was greatest for the younger persons in noisy jobs and for those who had the least experience of such jobs. The accident rate diminished with increasing age and a better understanding and experience of working in a noisy environment, with similar, though less obvious, changes noted for those located in quieter areas.

A similar result was obtained in a French study by Jessel (1977)[42] with accidents being three or four times more frequent in noisy situations than in quiet ones. Lees, Remeril and Wetherall (1980)[43] found no significant effect of noise on accidents. However, they only studied 140 workers and the effect of noise would have had to be very large for them to detect it.

Noweir (1984)[44] studied a sample of 2458 workers exposed to aveage noise levels ranging from 80-99dBA in different operations of three textile mills. The frequency and severity of accidents in the high noise departments were greater than in the low noise departments, although the difference was not statistically significant. Further analyses examined the extent to which the noise effects reflected personal, socioeconomic or occupational history factors. The results showed that none of these factors modified the extent of the difference between high and low noise departments.

In general, fatigue, lethargy, muscular tension, and lowering of alertness and efficiency are common symptoms in noisy work environments. All these symptoms can result in accidents. (Westman, Walters 1981)[45]

Accidents may be caused by persons being startled. Certain noises, especially those of an impulsive nature, may cause a startle reflex.

In noisy environments, the failure of workers to hear warning signals or shouts may lead to injury. Possible casual links have been suggested in the 1972 Code of Practice for Reducing the Exposure of Employed Persons to Noise which stated that *"by hindering communications and by masking warning signals noise may be the cause of accidents".*

3.15 Hearing Mechanism

The sensation of hearing is produced by a train of events which, in principle, is shared by other types of sensory mechanism in the body. The stimulus, in this case sound waves, activates the end organ, a complex mechanism which responds by movement of certain of its parts. The ear as a transducer converts sound energy into electrical energy which is sent to the receptive centres of the brain via electrical impulses (Melville, S Adams and Francis McManus, 1994)[45].

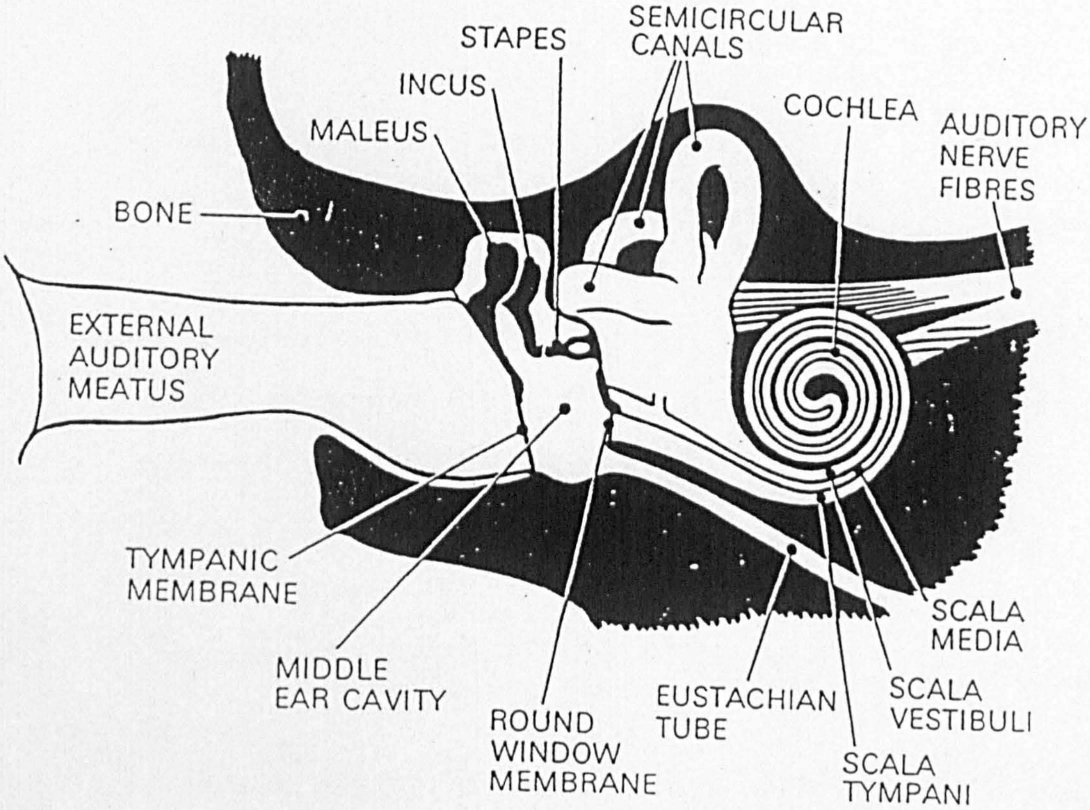
In order to understand the effects of excessive noise levels on the ear, it is necessary to understand first, the basic functions of each part of the ear, what losses of hearing result from causes other than noise and finally what effect noise has on the hearing mechanism.

3.16 Anatomy of the Ear

The general structure of the peripheral hearing mechanism is shown in (Figure 3.5) in a diagrammatic but partially realistic manner.

The events to be described start with the occurrence of sound pressure fluctuations in air; these in turn set into vibration the ear drum or tympanic membrane, which in turn actuates a level system of three very small bones, the auditory ossicles, situated in the air-filled cavity of the middle ear. The ossicles are grouped in such a way that the vibrations of the tympanic membrane are transmitted to the ossicle known as the malleus, which drives the second ossicle, the incus; and finally the third ossicle, the stapes to the oval window membrane which separates the air in the middle ear from the fluid filled spaces of the inner ear.

FIGURE 3.5 DIAGRAM OF THE MAIN COMPONENTS OF THE EAR



The oval window transmits the vibrations to the fluid of the inner ear which is contained in the coiled tubular canal or cochlea. The cochlea is divided into two halves throughout most of its' length by a partition, one side of which is in contact with the receptor organ, the organ of Corti (Figure 3.6).

The organ of Corti is a complicated system of cells and associated tissues, but essentially consists of several rows of hair cells, with supporting cells and structure which rest on a membrane (basilar membrane).

High frequency sounds are sensed in the first part of the cochlea while low frequency sounds pass to the end of the organ of Corti to be sensed there. The movement of the hair cells are translated into nerve impulses in the nerve fibres which run into the auditory nerve and by means of the differing location of the stimulated hair cells the characteristics of the sound waves are deciphered by the brain.

Two small muscles (Tensor tympani and Stapedius) are attached to the malleus and the stapes, and in response to a variety of stimuli, including very loud sounds, they contract and change the transfer efficiency across the chain of ossicles, incidentally providing some protection to the inner ear.

Equalisation of the pressure between the middle ear cavity and the external environment is obtained via the Eustachian tube which connects the middle ear with the upper part of the throat. When this tube becomes blocked, e.g. by upper respiratory infection, the loss of pressure equalisation results in reduced auditory sensitivity (Shell Safety and Health Committee, 1991)[47].

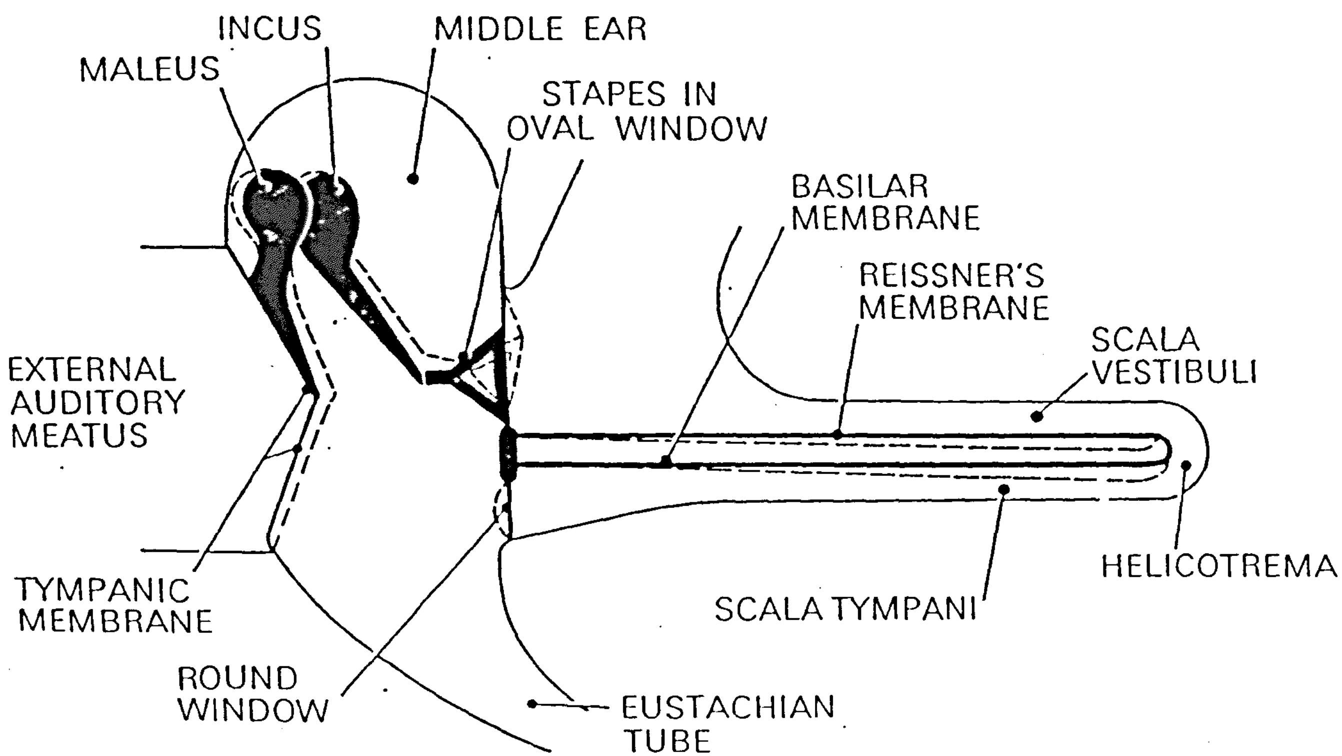


FIGURE 3.6 THE INTERNAL DIAGRAM OF THE EAR

In cases of permanent, noise induced hearing loss, changes can be found in the cochlea organ, ranging from minor changes in the hair cells to obvious damage and breakdown of the organ of Corti.

3.17 *Hearing Loss Due to Causes Other Than Noise*

Hearing defects not related to noise are referred to as conductive deafness, sensory-neural deafness or central deafness.

Conductive deafness is caused by an obstruction in the pathway from the exterior to the cochlea. The obstruction may be in the meatus and could simply be a foreign body, water or a build up of wax. The conductive defect may be in the middle ear itself. The communication, through the Eustachian tube, between the middle ear and the part of the back of the nasal cavity (naso-pharynx) allows infective processes in the latter to involve the middle ear. Infection may even extend to the mastoid air cells. Infection of the middle ear can occur with the common cold and with diseases such as measles and scarlet fever. Fluid collects in the middle ear, and the infective process may proceed to the formation of pus, and the tympanic membrane itself may rupture. This condition is known as otitis media (Ballantyne, T, 1977)[48] (Keith, R.W., 1980)[49].

Another condition where conductive defects occur is known as otosclerosis. This is where growth of bone in the neighbourhood of the oval window gradually interferes with the movement of the stapes. Sensorineural defects are in the cochlea itself or in the fibres of the auditory nerve. This form of deafness is a characteristic of growing older and the name presbyacusis denotes the connection with age (Davis, H., 1970)[50].

In late life a well-recognised aspect consists of changes in the cochlea near the base, where the hair cells degenerate to varying degrees and the nerve fibres carrying the message to the brain also degenerate.

Certain drugs are known to be capable of damaging the cochlea, as do diseases not specifically otological in nature, such as meningitis resulting from any one of a number of different kinds of infective agents (Hawkin, J.E., 1979)[51]. Virus diseases such as mumps and measles have been associated with damage to the organ of Corti (Davies, D.M., 1991)[52].

There is a third hearing impairment which is referred to as central deafness which cannot be attributed to abnormality of the cochlea or auditory nerve. This category of deafness is sometimes described as of intracranial origin, that is inside the space in the skull occupied by the brain and brain stem. Intracranial conditions which may have deafness as a symptom include various types of tumours or abscess formation in the brain, interference with the blood supply to parts of the brain, as may be caused by cerebral thrombosis or haemorrhage (Ballantyne, J, 1977)[48].

3.18 Histological Studies and Noise Induced Hearing Loss

Occupational causes are the most ubiquitous of noise induced hearing loss, but the additional effect of social and recreational exposure is important. Noise is thus a major public health problem, having the capability to produce hearing loss at any age. Usually long exposure to excessive sound levels produces a gradual deterioration in hearing which is of variable severity (Albert,. 1992)[53].

The Japanese Ministry of Labour has recommended that employers conduct periodic audiometric tests as a special medical examination for employees working in noisy environments. About 10% of the workers examined have shown some degree of abnormal findings every year for the past 10 years. For example, 154,261 workers employed in noisy environments received audiometric examinations in 1984. As a result 13,049 (8.5%) of them showed significant hearing loss due to occupational noise exposure (Takashi Magakita and Hajime Miura, 1986)[54].

A study carried out in Hong Kong, where the detrimental effect of industrial noise had been recognised gave results that 37.5% of workers worked in locations in which the noise level was in excess of Leqd 90 dB(A). Among examined subjects, 39.8% were exposed to Leq d 90 dB(A) and above and 18.6% were found to have industrial hearing loss (Chew and Lin, 1991)[55].

In Great Britain workers are exposed to potentially hazardous noise in most industries with powered machinery. Table3.5 shows the estimated number in manufacturing industry. Over all industries it is estimated that about 1.7 million persons may be exposed above the 85 dB(A) level and over 630,000 above the 90 dB(A) level (Health and Safety Commission, 1987)[6].

TABLE 3.5 Distribution of Exposed Workers In Great Britian

Noise Exposure	85 - 90 dB(A)	90 - 95 dB(A)	95 - 100 dB(A)	100 - 110 dB(A)	over 110 dB(A)
No. of persons (000s)	710	275	115	34.5	2.5
% of all employees in manufacturing industry	13.8	5.4	2.2	0.7	< 0.1

3.19 The Development Of Damage Risk Criteria

Much noise research has as its final objective the creation of damage risk criterion (DRC). As in all public health criteria, there are not only scientific questions that must be answered, but numerous social, economic and legal considerations.

The formation of DRC has been an evolutionary process. The first studies to define a criterion only measured the overall sound pressure levels of the noise in decibels without giving consideration to the frequency spectrum. It has been recognised that the overall intensity of noise was not sufficient to describe the potential for hearing loss and that noise frequency spectra must also be considered. Although exposure limits vary from one jurisdiction to another, a broad consensus holds that the risk of occupational deafness rises steeply if habitual exposure to continuous noise, or the equivalent, exceeds 80 dB(A) and that the risk becomes negligible below 80 dB(A). Exactly where between these two values the exposure limit should be set is the subject of discussion and some controversy (Atherley, 1989)[56].

In 1971, the Department of Labour published "Guidelines to the Department of Labour's Occupational Noise Standards" which established the basic permissible intensity of noise as 90 dB on the A-slow scale of a sound level meter for a duration of 8 hours per day. Exposures at different sound levels were regulated according to a 5-dB rule, i.e. for every 5-dB increase in the average sound level above 90 dB(A), the duration of exposure would be divided by 2. The upper limit of exposure to steady sound levels was set at 115 dBA regardless of duration. A limit for impact or impulse noise was set at 140 dB peak sound pressure level (Catlin, 1986)[20]

The Health and Safety Commission Regulations and Guidelines regarding prevention of damage to hearing from noise at work detail three action levels. Some basic measures are required at or above the "first action level", a daily personal noise exposure of 85 dB(A). Both these and additional measures must be taken at or above the "second action level" of 90 dB(A), or the "peak action level" of 200 pascals (Health and Safety Commission, 1987)[6]

The World Health Organisation (1986)[18] reported that the occupational limit adopted by a number of countries for noise is 85 dB. The allowable noise dose varies slightly between different countries but it is usually between 85 anb 90 dB(A) and is referred to as the criterion noise dose (ACGIH, 1987)[57]. Much of the impetus for this work has been derived from an industrial survey carried out jointly by the Medical Research Council and the National Physical Laboratory in the UK during 1963-68. They had succeeded in demonstrating a relationship between noise and hearing loss so that it is now possible to predict what proportion of a working population will experience a certain minimum amount of hearing loss if the noise levels and the length of exposure to them are known. The measure -ment of sound on the A weighting network has received wide acceptance for gauging noise hazards by the American Conference of Government Industrial Hygienists, Intersociety Committee, 1980. In the USA, Federal and State regulations aimed at safeguarding against excessive noise now cite exposure limits in dB(A).

3.20 Occupational Noise

The Noise at Work Regulations 1989 came into force on 1 January 1989, and are designed to protect people at work from suffering damage to their hearing. These regulations implement the requirements of EC Direcive 86/188/EEC (W. H. Bassett, 1989)[58]. The regulations stipulate three 'action levels'.

1. a first action level of 85dB (A)
2. a second action level of 90dB(A)
3. a peak action level of 200 pascals (equivalent to 140dB)

If the noise level in the workplace is above the first action level, then the employer shall ensure that a 'competent' person makes a noise assessment which is sufficient to:

1. identify which of the employees are so exposed, and
2. provide them with such information with regard to the noise to which those employees may be exposed as will facilitate compliance with the duties under the Health and Safety at Work Etc, Act 1974 and the Noise at Work Regulations 1989.

When the level lies between the first and second action level, the employer must provide suitable and sufficient ear protectors to employees who ask for them. These must be maintained by the employer in good condition. However, there is no duty either on the employer or the employee to ensure they are worn.

Where the exposure is above the second action level, the employer must provide suitable and sufficient ear protectors capable of keeping risk down to no more than that expected from the action levels. Employers and employees have a duty to ensure they are worn.

Areas in the workplace that are identified as being above the second action level must be identified and designated an 'ear protection zone'. These zones should be clearly marked with signs complying with BS5378: 1980 (British Standards Institute, 1980)[59] and it should be ensured that everyone entering the zones is wearing ear protection.

The peak action level is most likely to be encountered where cartridge operated tools, shooting guns or similar loud, explosive noisy devices are used, and workers exposed above this level will also be exposed to levels above 90dB(A).

3.21 Industrial Audiometry

In industrial environments where workers are exposed to noise levels which are likely to induce hearing loss, hearing conservation programmes must be implemented. Where engineering methods aimed at reducing ambient noise levels to below the prescribed level fail to do so, for whatever reason, personal protection methods should be used. Under such circumstances audiometry may serve as a valuable tool to monitor the effectiveness of environmental and personal control methods. Used as a screening test, the main objective of audiometry is to determine whether a worker has sustained a measurable degree of hearing loss, long before such hearing loss has become significant and thus a disability and handicap to the worker concerned. However, as a screening test audiometry should have acceptable validity in the practical scientific sense (Mets, 1985)[60]

Atherley concluded in 1984 that audiometry had never been conclusively and exhaustively tested for its overall scientific and social validity. He warned that occupational audiometry has the potential for prejudicing human rights in cases where being labelled as hearing-impaired might mean loss of job opportunities (Atherly, J., Johnson, N, 1981)[61]

Burns and Robinson stated in 1970 that no routine test for susceptibility to noise-induced hearing loss was available and that a given exposure carries a different degree of hazard for each individual so exposed. They state that in their opinion the employment of periodic monitoring of hearing by pure-tone, air-conduction audiometry is the only practical expedient after noise exposure has been reduced as much as possible. They recommend ear-protection and audiometry for all workers exposed to a noise level higher than 85 dB even though without ear- protection only a small minority exposed to a level of up to 90dB would be expected to show significant deterioration of hearing (Bunrs W., Robinson D. W. 1970)[62].

Hetu critically reviewed the effectiveness of audiometry in industry in 1979. He confirmed reference findings with regard to the unavoidable random error which is inherent in industrial audiometry even when all controllable variables are reasonably accounted for. He found that in pairs of automatic audiograms for 30 subjects taken with a 1-hour interval, 95% of the errors were spread between +5 and -5 dB (+ 2 SE) and that at high frequency (6000 Hz) the 2 SE value reached 8 dB. The major conclusion is that, in order to accept a difference between audiograms as meaningful, i.e. due to noise-induced hearing loss, the difference should exceed 10 dB at frequencies up to 4000 Hz, 15 dB at higher frequencies (4000 - 6000 Hz) and 20 dB at 8000 Hz (Hetu, R., 1979)[63].

Dobie concluded that criteria based on averaging a number of frequencies provide better indicators for noise-induced hearing loss than do single pure-tone frequencies. In the past, the value at 4000 Hz, the so-called "dip", had been considered a useful indicator. In Lane's study[4] there were clear indications that, with a criterion of 15 dB deterioration, the 1- frequency (4000 Hz) indication for incipient hearing loss is still valid, i.e. Lane's results did not confirm Dobie's conclusion in this respect. On the basis of their data the authors concluded that the STS (Significant Treshold Shift with 10 dB deterioration as criterion (at 500, 1000 and 2000 or 3000, 4000 and 6000 Hz) would provide a valuable and useful method for monitoring noise-induced hearing loss (Dobie, R.A., 1983)[64].

There is no doubt that the reliability and validity of audiometry in industry is questionable, but this makes it even more appropriate to evaluate its use as a screening method to identify incipient hearing loss at an early stage. Audiometry measures hearing thresholds and nothing else on a set scale of units. The commonly used 5 dB intervals is relative to the expected deterioration of hearing thresholds on the time-growth curve of noise-induced hearing loss. For the purpose of evaluating industrial audiometry, it may be stated that sensitivity, which is the power to assign correctly a high proportion of cases of incipient noise-induced hearing loss, is a measure of validity under conditions where specificity can be made to approach 100%(Bryan & Tempest, 1990)[65].

For use as a screening method, audiometry at recommended intervals should be evaluated against predetermined criteria of which a deterioration of 10 dB at 4000 Hz compared with the preceding audiogram is only one. It is advocated that the use of the concept of STS with 10 dB as criterion for the low frequency (500, 1000 and 2000 Hz) as well as for the high frequency range (3000, 4000 and 6000 Hz) should be considered and these values should be used as warning signs and action levels for audiometry in industry (Mets, 1985)[60].

Audiometry should follow accepted standards (Cf.ISO/6189 (1983)) with an audiometry frequency schedule as detailed (Table 3.6) which will identify early noise-induced hearing loss in 99% of the working population.

TABLE 3.6 Audiometry Standards

PERSONAL NOISE DOSE	FREQUENCY
< 80 dB(A)	no audiogram
> 80 dB(A)	baseline audiogram before employment in that particular job. Initial test should be repeated within a period of 6-12 months.
80 - 90 dB(A)	once every four years
90 - 95 dB(A)	once every two years
> 95 dB(A)	at least yearly

3.22 Hearing Conservation Programme(HCP)

In both industrial and non-industrial noise environments, the control of NIHL is primarily through prevention, stressing a decrease in existing noise and, a decrease in exposure to noise levels or both.

An HCP should include a pre-placement hearing test and periodic repeat tests.

These tests should detect the presence of existing hearing loss and determine cochlear injury due to noise exposure. If a significant change in hearing level is observed at any frequency in either ear, the following should be considered to prevent further hearing loss;

(a) providing and encouraging the use of ear protection devices

(b) reduce noise level at source and

(c) limit employee's exposure time or remove employee from the noise environment (Hammernik & Davis, 1995)[66].

If the plant noise is found to be excessive, the noise dosage a worker receives should be controlled through lowering the plant noise level or reducing exposure time or by the use of ear protection devices (EPD's).

General noise level surveys should be carried out at sites to determine where excessive noise levels exist and to identify the potential risk to employees. It is essential that a noise survey be carried out when the maximum amount of noise is emitted. If the noise levels exceed the es tablished safety standard and criteria, action must be taken to reduce the exposure. All workplace noise should be reduced, at source, so far as is reasonably practicable. Plant noise can be lowered by:

(a) *Replacement of noisy machines with quieter ones.*
(b) *Relocation of noisy machines away from corners and walls.*
(c) *Avoiding installation of noisy machines in small cubicles where there are workers.*
(d) *Installation of noise-absorption materials on walls and ceilings.*
(e) *Reduction in vibrating surfaces - use of anti-vibration mounts*
(f) *Reduction of the driving force, e.g. running machines at lower speeds.*
(g) *Directing sound away from the point of interest, e.g. noise shields.*
(h) *Enclosing noisy machines* (J. Jeyarnalrocm, 1992)[17].

It should be stressed that due to the logarithmic nature of the decibel scale it is essential to control the principal source of noise first even if this is not the easiest to control. Controlling non-principal sources only will have minimal effect on the overall noise level (O'Malley, 1990)[67].

Noise specifications should be developed for all new machinery and processes, taking account of the existing area noise environment and incorporated in equipment requisitions. (Concawe, 1985)[68].

If the engineering noise control proves to be impractical then the aim would be to reduce the employee's exposure well below the recommended level by changing shift patterns, etc. However, a secondary noise control measure is the issue of hearing protection. Any area where persons may be exposed to noise in excess of the statutory limit should be identified as a "hearing protection area". Entry to such areas should be supervised and should be strictly conditional upon the wearing of effective hearing protectors. A notice prohibiting entry to persons not wearing hearing protectors should be displayed near every entrance to a hearing protection area.

3.23 *Personal Protection*

Plugs reduce the noise reaching the mid-ear frequencies. Ear-muffs on the other hand, are more effecive protectors especially for frequencies between 500 Hz and 1 kHZ. In areas with extremely high noise levels, ear-plugs do not afford sufficient protection and the individual should be advised to wear both ear-plugs and ear-muffs (David Garfield, 1990)[69]

Impulsive noise is generally considered to be 'relatively' short in duration, and often intense in presentation. This can occur at regular intervals throughout a working day or only sporadically. In many industrial situations impulsive noise components are superimposed on a background of continuous noise (Hamernick & Davis,1995)[66].

The range of hearing protectors now commercially available is very wide. The key purpose of hearing protection is to reduce the noise exposure level of the wearer. Reduction in noise exposure level by hearing protectors determines the protection which they afford against noise. Else (1973) set out the principles involved. It has been widely understood for a long time that the protection afforded by hearing protectors depends on their attenuation. Else pointed out that there was another, equally important factor to be considered - the percentage of time during which the hearing protection is worn (Hamernick & Davis, 1995)[66].

In circumstances where noise levels are high and hearing protection is relied upon, attention must be paid to comfort and acceptability of hearing protectors, because these will materially influence the extent to which people actually wear the protection provided (Hamernick & Davis, 1995)[66]

The two main types of hearing protectors are ear-muffs nd ear-plugs, collectively known as hearing protection devices (HPDs). Ear-muffs are designed to completely cover the external ear and a foam-filled cushion seal ensures a close fit to the head. There are three main types of ear-plugs (Waldron, 1989)[2]:

1. glass down
2. soft, solid plastic or silicone rubber inserts
3. plastic foam plugs

Advantages and disadvantages of muffs and plugs are:

1. Muffs more visible - easier to check if they are worn
2. Muffs not so easily lost because they are bigger
3. People with ear infections should not wear ear-plugs but can wear muffs
4. Muffs come in one size which fit most heads
5. Dirt and toxic matter may be transferred to ear if plugs inserted with dirty hands
6. Plugs are cheaper than muffs

7. Plugs msore comfortable in hot environments
8. Glasses, long hair or facial hair does not interfere with plugs, but prevents a good seal for muffs
9. Plugs more suitable where the head has to be manoeuvred in a confined space

Personal protection devices place extra stress on the workers, and should be used as a last resort. There are two types of hearing protection devices available - ear-plugs and ear-muffs. The ear-plugs are inserted into the ear canals to reduce the noise energy reaching the middle and inner ear. They come in different shapes, eg, rod-shaped and conical, sizes and materials. The amount of protection (attenuation) afforded depends on size, fit and how the plug is inserted into the ear. Ear-muffs are shaped like cups and cover the whole external ear. The amount of protection afforded depends on the seals (J. Jeyaratnam, 1992)[17].

The following factors should be considered in the selection of ear-defenders:

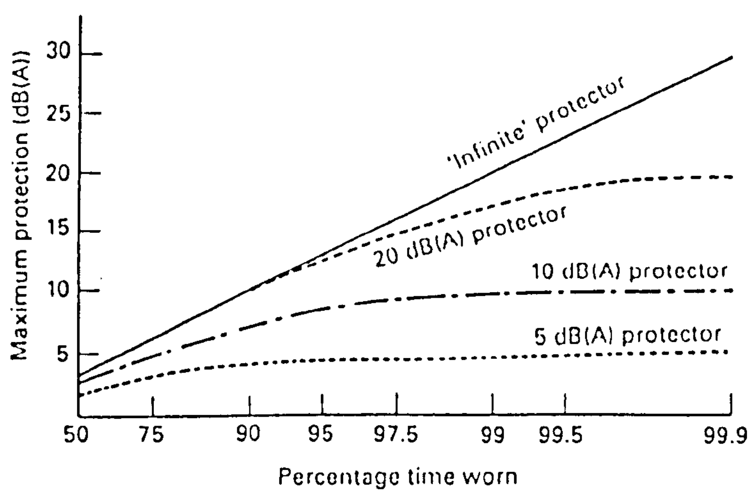
1. Whether it is to be used once and discarded, or be repeatedly used
2. Degree of comfort for user
3. Initial cost as well as maintenance cost
4. The attenuation provided

An effective HCP will vary the styles of hearing protection devices available until satisfactory types are found that can and will be worn by employees. Failure of any employee to wear properly a hearing protective device, even for a small percentage of the time that the employee is in the noise, can dramatically reduce the effectiveness of the device (Berger, 1980)[70].

Attention must be paid to comfort and acceptability of hearing protectors, because this will materially influence the extent to which people actually wear the protection which is provided.

It has been shown that removing the HPD for only 15 min of an 8 hour continuous exposure will reduce the protection provided by a high performance HpD from 30dB to 15dB overall, and from 20dB to 14dB for a less efficient protector See Figure (3.7) (H A Waldron,, 1989)[2].

FIGURE 3.7 Maximum Hearing Protection As Function of Hearing Time



Another important component of an effective hearing conservation programme is education of both management and employees.
The education programme should be in the form of talks which include a brief description of hearing, the harmful effects of noise, the desirability

of noise abatement, the role of audiometry and the use of hearing protection devices. Emphasis should be placed on the social handicap of NIHL.

A well documented HCP should be maintained covering workplace noise measurements, information regarding noise control measures, selection, use and maintenance of personal hearing protective devices, calibration and maintenance of all measuring equipment, education and training programmes, national legislation and guidelines.

The participation of the worker is essential to any programme aimed at maintaining the health of the worker. With respect to noise-induced deafness, workers should be made aware that continuous exposure to excessive noise levels of noise over a long period of time will result in permanent hearing loss. An awareness that excessive noise can cause deafness is by itself inadequate as this needs to be translated into appropriate practice through training and education. The worker must be trained in the proper use of protective equipment, such as ear plugs or other ear protection devices.

3.24 GLOSSARY OF TERMS USED IN THIS CHAPTER

A-Weighted Sound Level: The ear does not respond equally to all frequencies, but is less sensitive to low and high frequencies than it is at medium or speech range frequencies used in noise analysis (typically 20Hz to 20 kHz). Thus, to obtain a single number representing the sound level of a noise containing a wide range of frequencies in a manner representative of the ear's response, it is necessary to reduce the effect of the low and high frequencies with respect to the medium frequencies. The resultant sound level is said to be A-weighted, and the units are dBA. The A-weighted sound level is also called the noise level.

Ambient Noise: All-pervasive noise associated with a given environment.

Amplitude: The amplitude of sound may be described in terms of either the quantity of sound produced at a given location away from the source or the overall ability of the source to emit sound. The amount of sound at a location away from the source is generally described by sound pressure or sound intensity while the ability of the source to emit sound is described by the sound power of the source.

Analysis: The analysis of a noise generally refers to the examination of the composition of noise in its various frequency bands such as octaves or third-octave bands.

Audiogram: A graph showing hearing loss as a function of frequency.

Audiometer: An instrument for measuring hearing sensitivity or hearing loss.

Background Noise: The total of all noise in a system or situation, independent of the presence of the desired signal. In acoustical measure--ments, the term "background noise" is also used with the same meaning as "residual noise".

Band Centre Frequency: The designated (geometric) mean frequency of a band of noise or other signal. For example, 1000 Hz is the band centre frequency for the octave band that extends from 707 to 1414 Hz, or for the third-octave band that extends from 891 to 1123 Hz when more detailed information about a complex sound is required, the frequency from 20 Hz to 20 kHz can be divided up into sections or bands. This is done with electronic filters which reflect all sound with frequencies outside the selected band.

Band: A segment of the frequency spectrum.

Bell: Ten times a decible.

Broadband noise: Noise made up of a wide frequency spectrum in which no component is unduly prominent.

Conductive hearing loss: Hearing loss caused by blockage of outer ear or damage to middle ear.

Continuous Sound Spectrum: A continuous sound spectrum is composed of components that are continuously distributed over a frequency region.

dB(a): A decibel scale weighted in favour of frequencies audible to the human ear.

Decibel: Is a ratio between a measured quantity and agreed reference level. One tenth of a bel. Abbreviation dB. Ndb + 10 log (W_2/W_1). commonly used to compare power levels W_2 and W_1.

Dosimeter: A special purpose integrating sound level meter carried by an industrial worker to measure accumulated noise exposure.

Frequency: The frequency of sound describe the rate at which complete cycles of high and low pressure regions are produced by the sound source. Now expressed in Hertz (Hz).

Hearing Loss: At a specified frequency, an amount in decibels, by which the threshold of audibility for that ear exceeds a certain specified audiometric threshold, that is to say, the amount by which a person's hearing is worse than some selected norm. The norm may be the threshold established at some earlier time for that ear, or the average threshold for some large population, or the threshold selected by some standard body for audiometric measurements.

Hertz: Unit of measurement of frequency, numerically equal to cycles per second.

Impulse Noise: Sound with a rapid increase in sound pressure level such as produced by a punch press.

Leq: Equivalent continuous sound level. The dB(A) level which would produce the same A-weighted sound energy over a stated period of time.

Noise Dose: The product of noise level and exposure time.

Noise Induced Hearing Loss (NIHL): The raising temporarily or permanently of the minimum pressure level that can be heard, as a result of excessive noise exposure.

Octave: An octave is the interval between two frequencies, one of which is twice the frequency of the other.

Presbyacusis: Hearing loss mainly for high tones due to advancing age.

Pure Tone: A sound wave whose wave form is that of a sine wave.

Root Mean Square (RMS): The square root of the arithmetic average of a set of squared instantaneous values.

Sound Level Meter (SLM): An instrument comprising a microphone, an amplifier, an output meter and frequency-weighting network which is used for the measurement of noise.

Sound Power: The total amount of energy radiated into the atmospheric air per unit time by a source of sound.

Sound Pressure: (1) The minute fluctuations in atmospheric pressure that accompany the passage of a sound wave; the pressure fluctuations on the tympanic membrane are transmitted to the inner ear and give rise to the sensation of audible sound; (2) For a steady sound, the value of the sound pressure averaged over a period of time. Sound pressure is usually measured in newtons per square metre (N/m2) where 1N/m2 = 1 pa.

Sound Pressure Level (SPL): The root-mean-square value of the pressure fluctuations above and below atmospheric pressure due to a sound wave expressed in decibels as a reference pressure (2×10^{-2}pa).

Steady State Sounds: Sounds whose average characteristics remain constant in time. An example of steady-state sound is an air conditioning unit.

Temporary Threshold Shift (TTS): A temporary impairment of hearing capability as indicated by an increase in the threshold of audibility. By definition, the ear apparently recovers after a given period of time. Sufficient exposures to noise of sufficient intensity, from which the ear never completely recovers, will lead to a permanent threshold shift (PTS) which constitutes hearing loss.

Threshold Shift: An increase in a hearing threshold level (i.e. hearing loss) at a given audiometric frequency.

Tinnitus: A subjective sense of "noises in the head" or "ringing of the ears" for which there is no observable cause.

CHAPTER 4

NOISE SURVEY AT DON & LOW

4.1 Survey Sites

Survey on the exposure to noise of shift workers at Don & Low was carried out at the four sites:-

1. *Newford Park, Forfar*
2. *St. James Works, Forfar*
3. *Canmore Works, Forfar*
4. *Wallace Works, Perth*

These surveys were carried out in accordance with the Health and Safety Executive's Noise Guide No. 3 "Equipment and procedures for noise survey", HMSO, 1990.

Area noise levels were measured using a precision sound level meter in (CEL 373B with octave band analysis) in the slow mode. The sound level meter was calibrated in the OHU I(Occupational Hefgien Unit) laboratory using a pistonphone and on-site before and after sampling using an acoustic calibrator. Area levels are reported in dB(A).

Where levels are variable, average levels were measured using a sound level meter in an integrating mode.

Personal exposures were measured over representative time periods using noise dosimeter (Bruel & Kjaer type 4428 IS and Metrosonic dB 301 IS and Larson Davids IMS 710) according to CONCAWE report 3/84 with the microphone attached to the top of the shoulder pointing up. Exposures are reported in dB(A) LEP'd which is 24 hour exposure expressed as the equivalent continuous sound pressure level for an 8h reference period.

Octave band analyses were carried out on selected noise sources to evaluate the effectiveness of hearing protectors in use and alternatives.

If the engineering noise control proves to be impractical then the aim would be to reduce the employee's exposure well below the recommended level by changing shift patterns etc. However, a secondary noise control measure is the isue of hearing protection. Any area where persons may be exposed to noise in excess of the statutory limit should be identified as a 'hearing protection area'. Entry to such areas should be supervised and should be strictly conditional upon the wearing of effective hearing protec tors. A notice prohibiting entry to persons not wearing hearing protectors should be displayed near every entrance to a hearing protection area.

An effective HCP will vary the styles of hearing protection devices available until satisfactory types are found that can and will be worn by employees. Failure of any employee to wear properly a hearing protective device, even for a small percentage of the times that the employee is in the noise, can dramatically reduce the effectiveness of the device (Berger, 1980)[70] Effective motivation must be provided in order to induce employees to wear hearing protection devices properly. Attention must be paid to comfort and acceptability of hearing protectors, because this will materially influence the extent to which people actually wear the protection which is provided.

Another important component of an effective hearing conservation pro gramme is education of both managment and employees. The education programme should be in the form of talks which include a brief description of hearing, the harmful effects of noise, the desirability of noise abatement, the role of audiometry and the use of hearing protection devices. Emphasis should be placed on the social handicaps of NIHL.

A well documented HCP should be maintained covering workplace noise measurements, information regarding noise control measures, selection, use and maintenance of personal hearing protective devices, calibration and maintenance of all measuring equipment, education and training programmes, national legislation and guidelines (Stevens, Royster, 1980)[71].

4.2 Survey Reports

Noise surveys have been done in all sites of Don & Low. See Table(4.1)

TABLE 4.1 Occupational Hygiene Report

Title:	**A short survey of exposure shift workers to noise at Newfordpark, St. James Works, Canmore Works and Wallace Works**
Survey Type:	**Short survey of exposure.**
Agent:	**Noise**
Purpose:	**To provide information on area levels and exposures. To make recom mendations for control.**

The results of the surveys of the four sites are reported separately in this document with information given on the manufacturing process at each site, the population/jobs per shift and shift system and tables indicating exposure of noise at locations and in specific jobs, See table (4.1).

They consist of octave band frequency analysis for specific noise sources. These levels are given in dB. From these figures the noise level at the unprotected ear has been calculated by applying the standard A weighting and summing the levels at each frequency. Using manufacturers' data on performance at each frequency and using one standard deviation, as recommended by the HSE, the noise level at the protected ear has been calculated. In general hearing protection which achieves a noise level at the ear of 80 dB(A) or less is considered suitable for use in terms of attentuation.

4.3 Methods

Table 4.2 indicates the methods and equipment used in carrying out the surveys at the four sites.

TABLE 4.2 Equipments And Methods Used For The Noise Environment Survey

Sound Level Meter:		Computer Engineering Ltd Model 393B precision sound level meter with octave band analysis. Model 186/3F 1/2" condenser microphone
	Grade:	IEC 651 type 1
	Calibration:	Calibrator type 177

Dosimeters:		Bruel and Kjaer Model 4428 noise dosimeters Model 4125 1/2" condenser microphone Model ZEO300 preamplifier and cable
	Grade:	IEC 651 type 1 (precision grade)
	Frequency Range:	10 Hz to 10 kHz "A" weighted to IEC R123
	Crest Factor:	30 dB
	Range:	80 to 140 dB(A)
	Calibration:	Calibrator type 4230, 93.6 dB acoustic calibrator checked against pistonphone type 4220, S/N 536743, calibrated by manufacturer

Dosimeters:		Metrosonics Model dB 301A IS noise dosimeters MK301 High range microphone
	Grade:	ANS1 SI.4-1971 type II
	Frequency Range:	"A" weighted
	Crest Factor:	10 dB
	Range:	60 to 133 dB(A)
	Calibration:	Metrosonics calibrator 102 dB at 1000 Hz

Dosimeters:		Larson Davis IM710
	Grade:	ANSI SI.4-1971 type II
	Frequency Range:	"A" weighted
	Crest Factor :	40 dB(A)
	Range:	35 to 145 dB(A)
	Calibration:	Band k calibrator type 4220

4.4 Newford Park

4.4.1 Manufacturing Process

Polypropylene fibre is manufactured within this site and is produced by three separate processes:-

(a) spinneret

(b) slit film

(c) multifilament

In each case a heated extruder is used to produce a type of extrudate which ends up as a continuous filament collected onto a series of winders. Some fibres are further twisted for strength on the twisting frames but these are not operated on every shift.

There is a mechanic and an electrician on each shift but major work is carried out by day shift craftsmen.

Metal winding cores are recovered by one person on the early and late day shifts. When work requires there is some flexibility in jobs.

Access is required to all rotating equipment.

4.4.2 Shift System

Newfordpark operate a day shift and a shift pattern as follows:-

Days	=	0800 to 1630 hrs
Shifts	=	1600 to 2400 hrs
		2400 to 0800 hrs
		0800 to 1600 hrs

7 days or 4-5 on with 2-3 days off during holiday periods.

4.4.3 *Population/Jobs Per Shift*

The job titles and numbers in each job per shift can be seen in table (4.3) along with an indication of the hours worked per day, per week and per month.

TABLE 4.3 Population/Jobs Per Shift At Newford Park

Job Title	Numbers in Job	Hours/ Day	Hours/ Week	Hours/ Month
Extruder Oper. - Slit Film	2	8	36	144
Extruder Oper. multifilament	2	8	36	144
Extruder Oper. - slit film	6	8	36	144
Extruder Oper. - spinneret	2	8	36	144
Twister	1	8	36	144
Materials Handler	1	8	36	144
Lead hand - slit film/multifil	1	8	36	144
Lead hand - slit film	1	8	36	144
Lead hand - spinneret	1	8	36	144
Mechanical Fitter	1	8	36	144
Electrical Fitter	1	8	36	144
QC	1	8	36	144
Shift Team Leader	1	8	36	144
Tube Recovery	1	8	36	144

4.4.4 *Exposure in Certain Areas Using Octave Centre Band Frequency*

Tables (4.4a & 4.4b) details the exposure (in decibels) in specific areas and Lines using the various octave centre band frequency levels. The exact positions of these areas can be seen in Figures (4.4a, 4.4b, 4.4c, 4.4d, 4.4e, 4.4f, 4.4g, 4.4h).

TABLE 4.4a Octave Centre Band Frequency (Hz) LOCATION at Newford Park

Octave Centre Band Frequency (Hz)	Line 57 Winders Fig. 4.1b, Pos. A	Line 56 By Fans Fig.4.1b Pos. B	Line 11 Winders Fig. 4.1c Pos.C	Between Line 10 and 11 Oven Extruder Fig.4.1c, Pos.D	Line 54 By Fans Fig. 4.1c, Pos.E	Line 13 Winders Fig. 4.1d Pos.F	Between Line 13 and 14 Elevator Fig. 4.1e, Pos.G	
31.5	78	77	78	78	70	75	58	54
63	83	79	78	78	73	84	60	60
125	85	77	82	81	82	83	64	68
250	91	79	84	86	84	86	73	75
500	87	80	86	88	84	85	80	84
1,000	87	81	86	89	84	87	81	89
2,000	82	81	83	84	83	88	80	80
4,000	76	78	81	79	75	84	79	74
8,000	69	71	76	70	65	76	73	67
dB (Lin)	94	88	92	95	90	93	85	88
dB (A)	91	86	90	92	89	92	86	90

Table 4.1b Octave Centre Band Frequency (Hz) LOCATION at Newford Park

Octave Centre Band Frequency (Hz)	Between Line 13 and 14 Extruder Fig.4.1e, Pos. H	By Twister Fig.4.1e, Pos. I	Pumping Station Fig.4.1f, Pos.J	Pumping Station Fig.4.1f, Pos. K	Line 29 Winders Fig.4.1g, Pos.L	Between Line 27 and 28 Oven Fig.4.1g, Pos.M	Between Line 25 and 26 Oven Fig.4.1g, Pos.N	Line 26 Winders Fig.4.1g, Pos. O
31.5	57	65	77	174	75	80	77	75
63	58	74	78	74	82	84	78	79
6,125	73	85	97	96	80	83	83	82
250	74	84	92	90	84	91	85	84
500	84	84	90	94	86	93	87	86
1,000	84	84	92	91	84	88	88	84
2,000	79	85	86	82	83	82	81	82
4,000	74	84	80	76	79	76	76	79
8,000	65	80	70	68	75	72	70	74
dB(Lin)	84	92	101	105	91	96	92	92
dB(A)	77	91	95	95	89	93	91	92

FIGURE 4.1a PLOT PLAN OF NEWFORD PARK

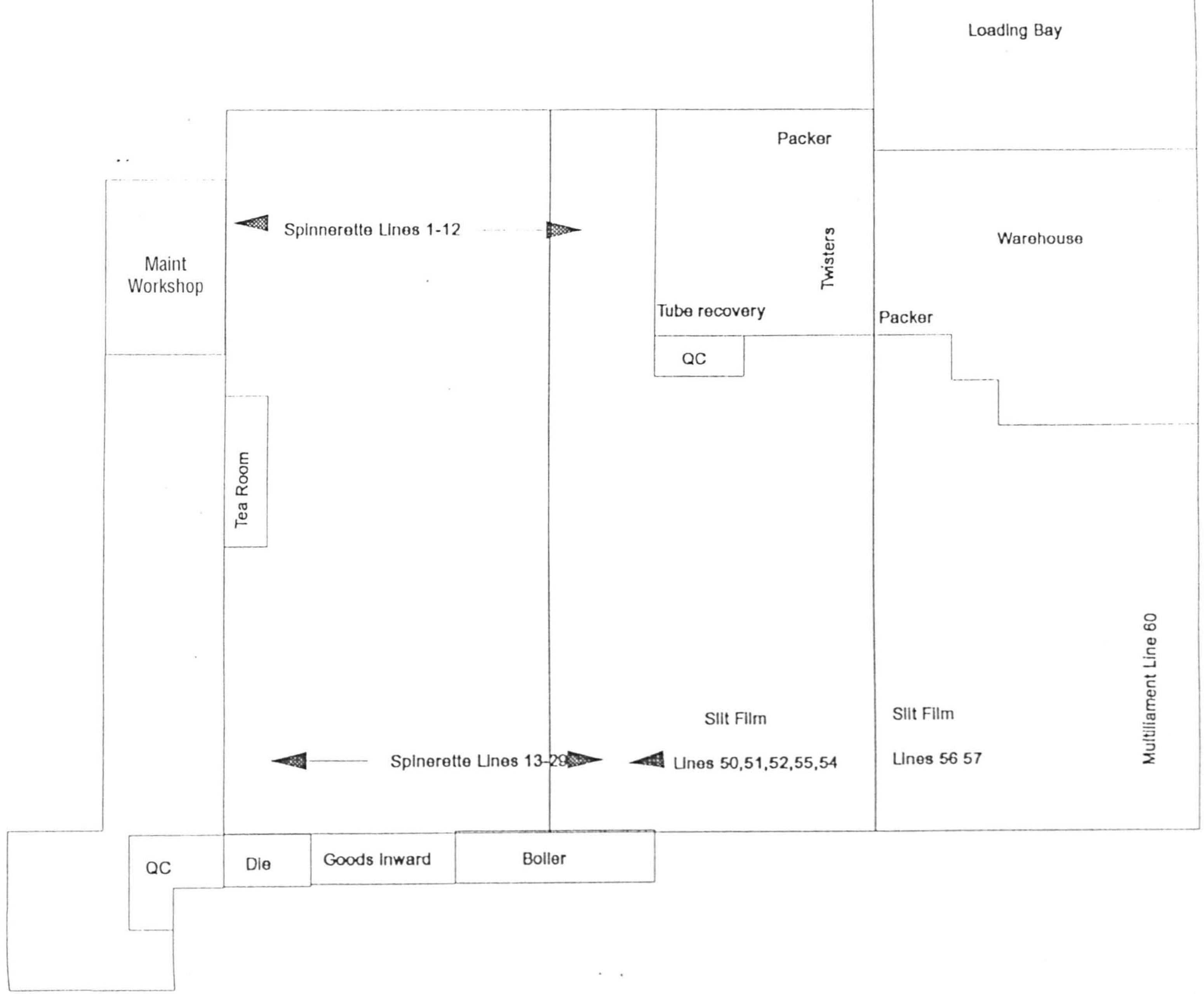


FIGURE 4.1b NOISE LEVELS IN dB(A) AT NEWFORD PARK

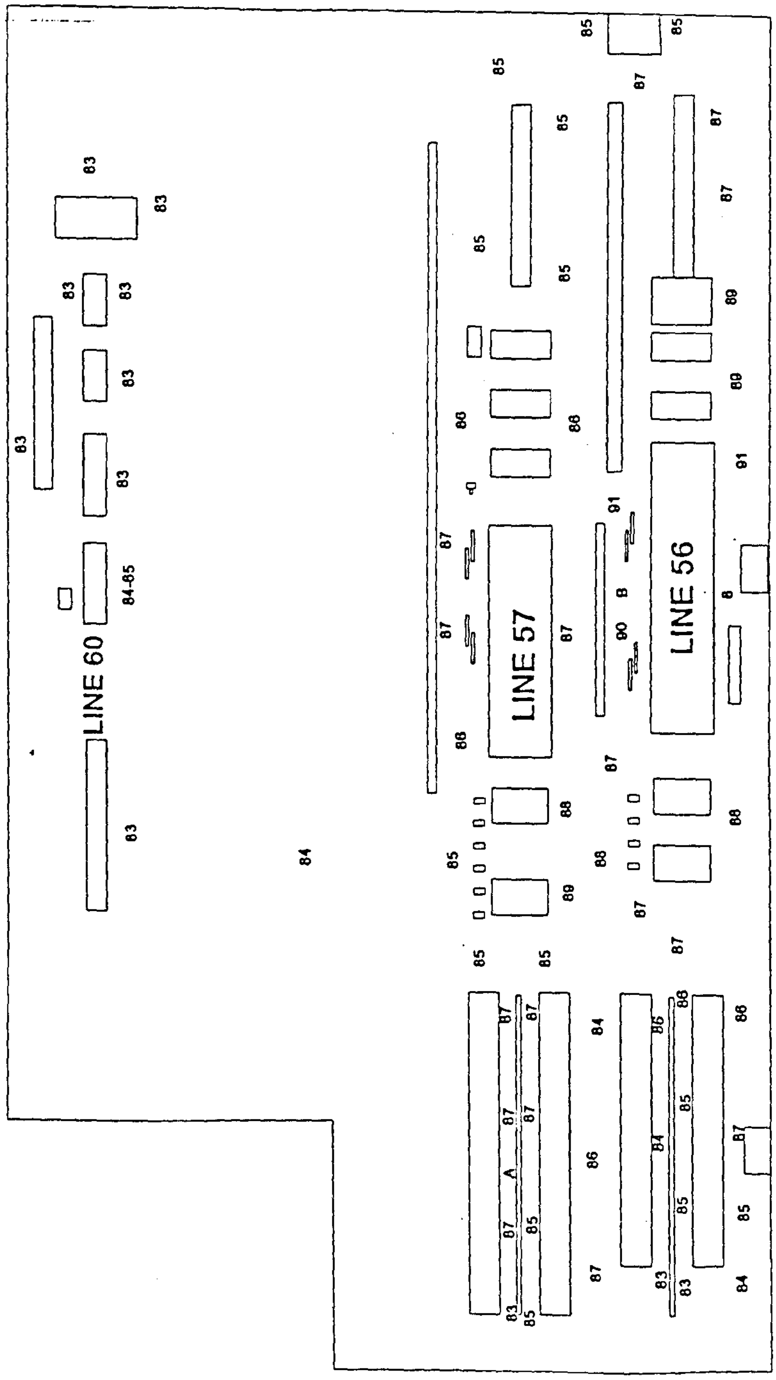


FIGURE 4.1c **NOISE LEVELS IN dB(A) AT NEWFORD PARK**

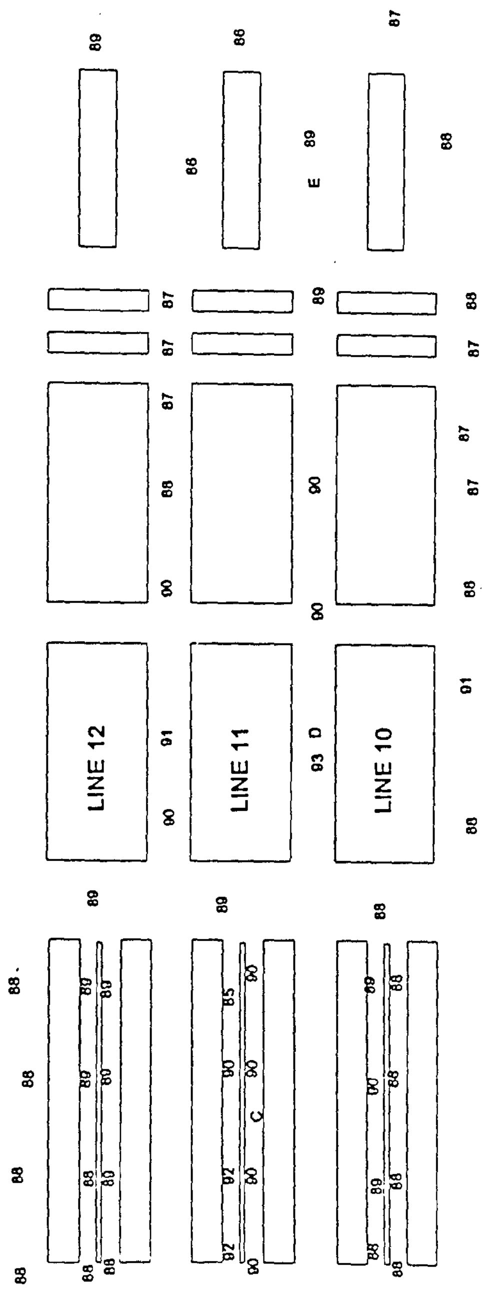


FIGURE 4.1d NOISE LEVELS IN dB(A) AT NEWFORD PARK

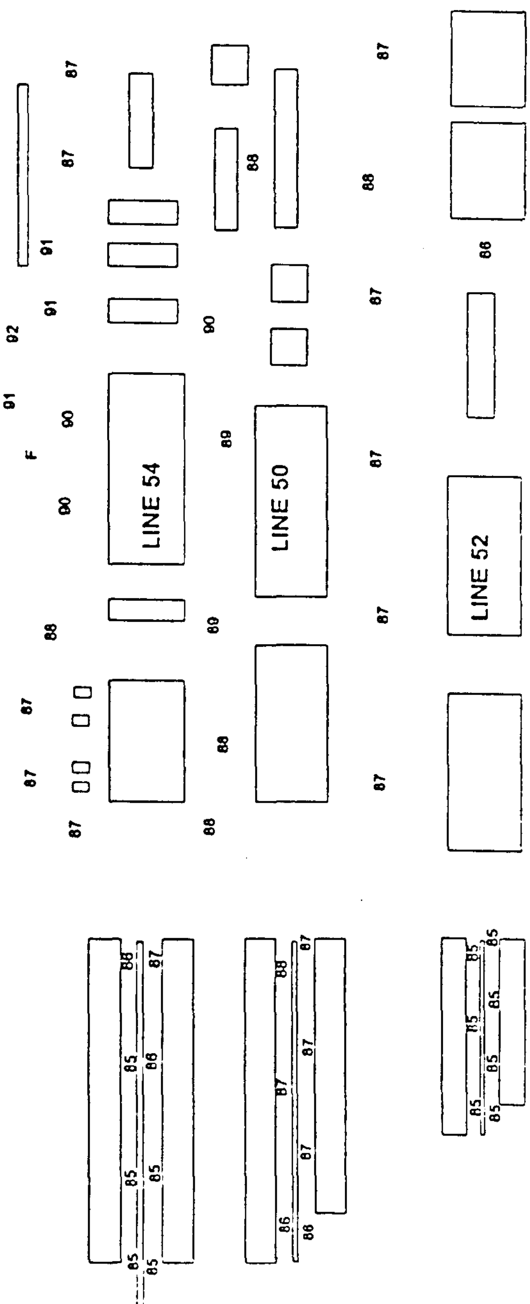


FIGURE 4.1e NOISE LEVELS IN dB(A) AT NEWFORD PARK

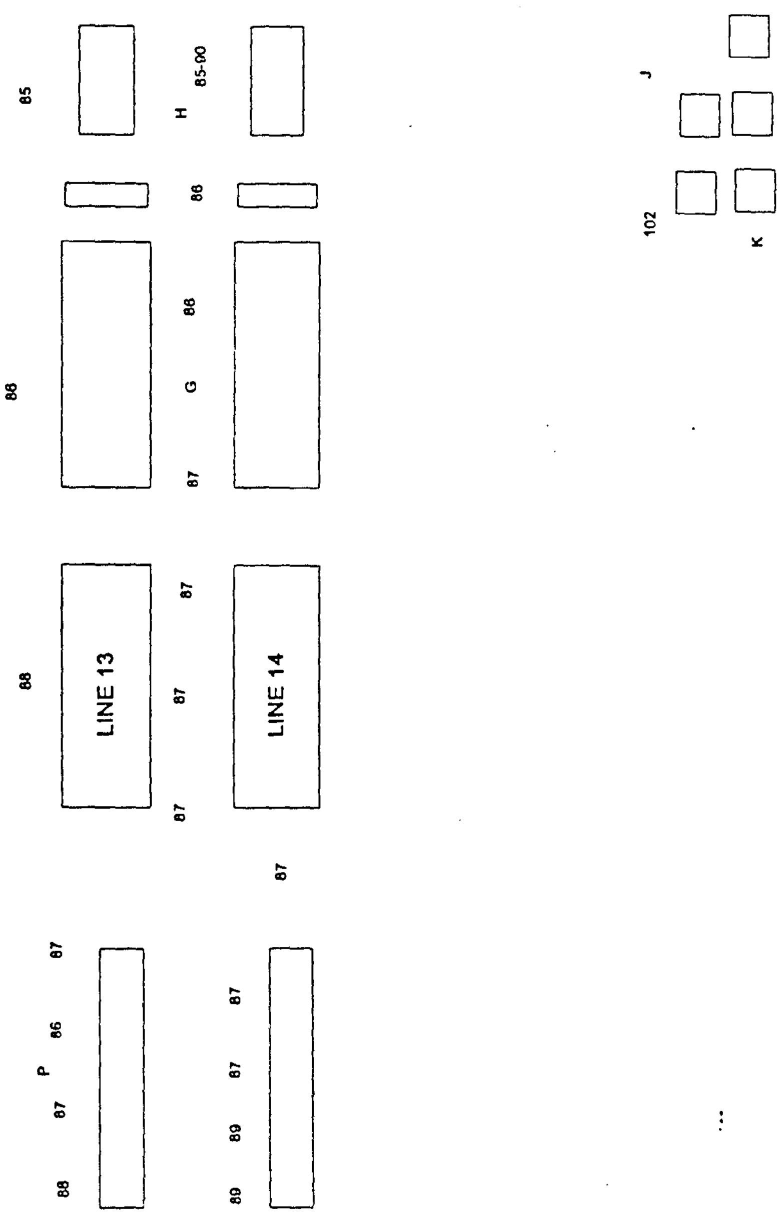


FIGURE 4.1f NOISE LEVELS IN dB(A) AT NEWFORD PARK

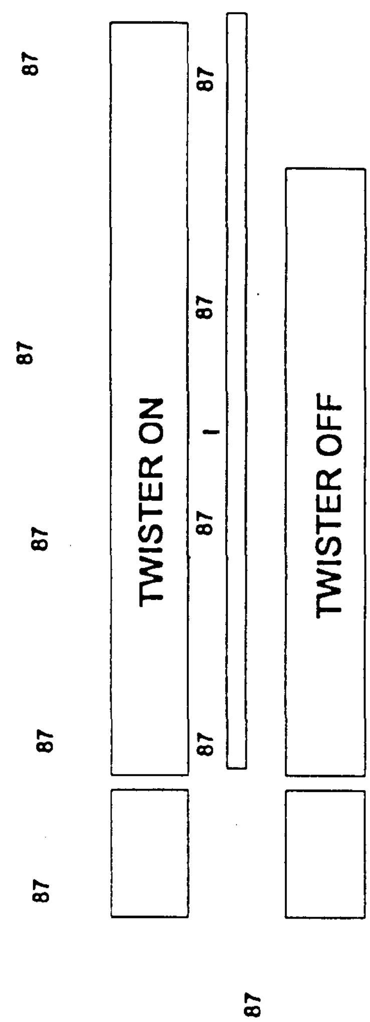


FIGURE 4.1g NOISE LEVELS IN dB(A) AT NEWFORD PARK

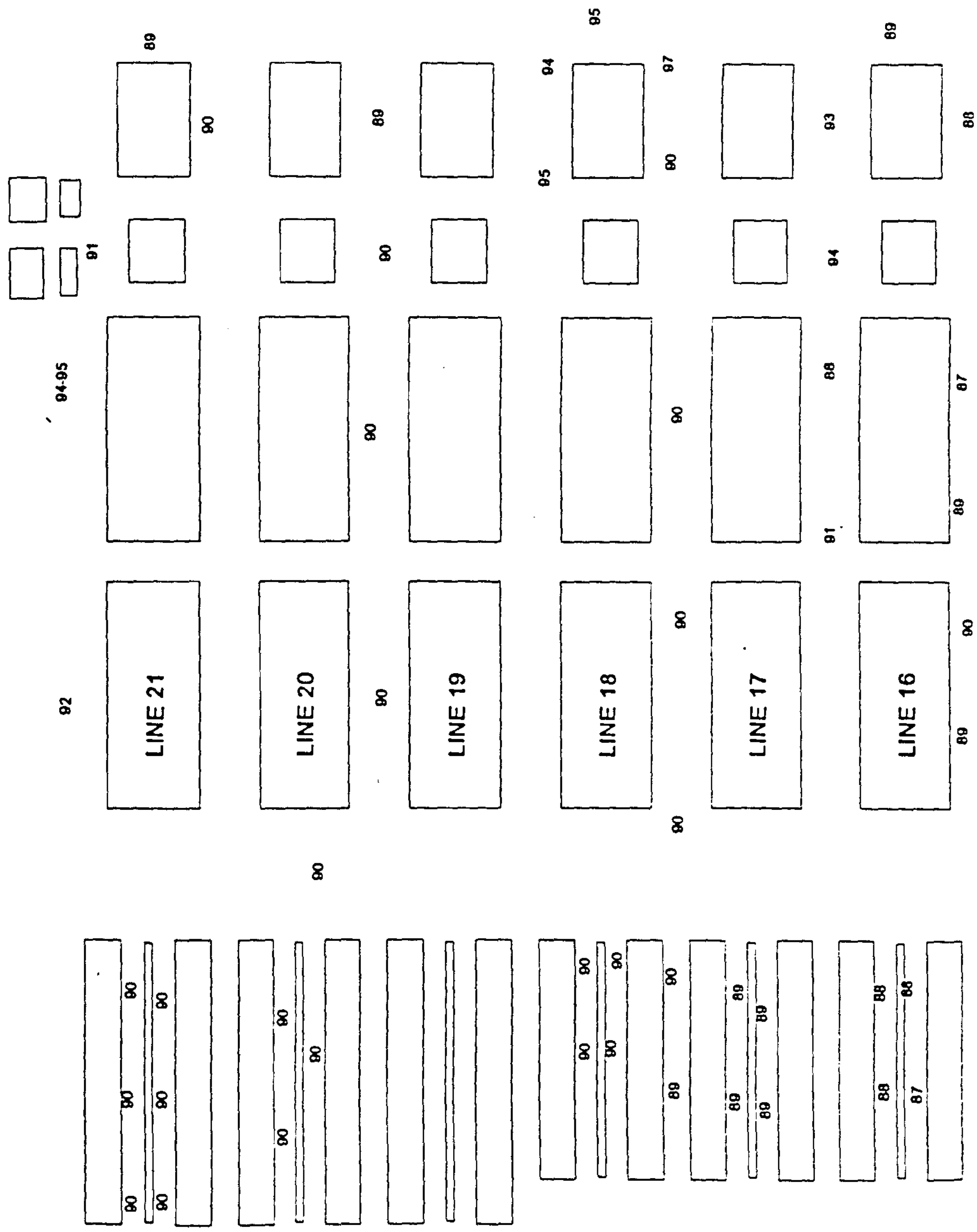
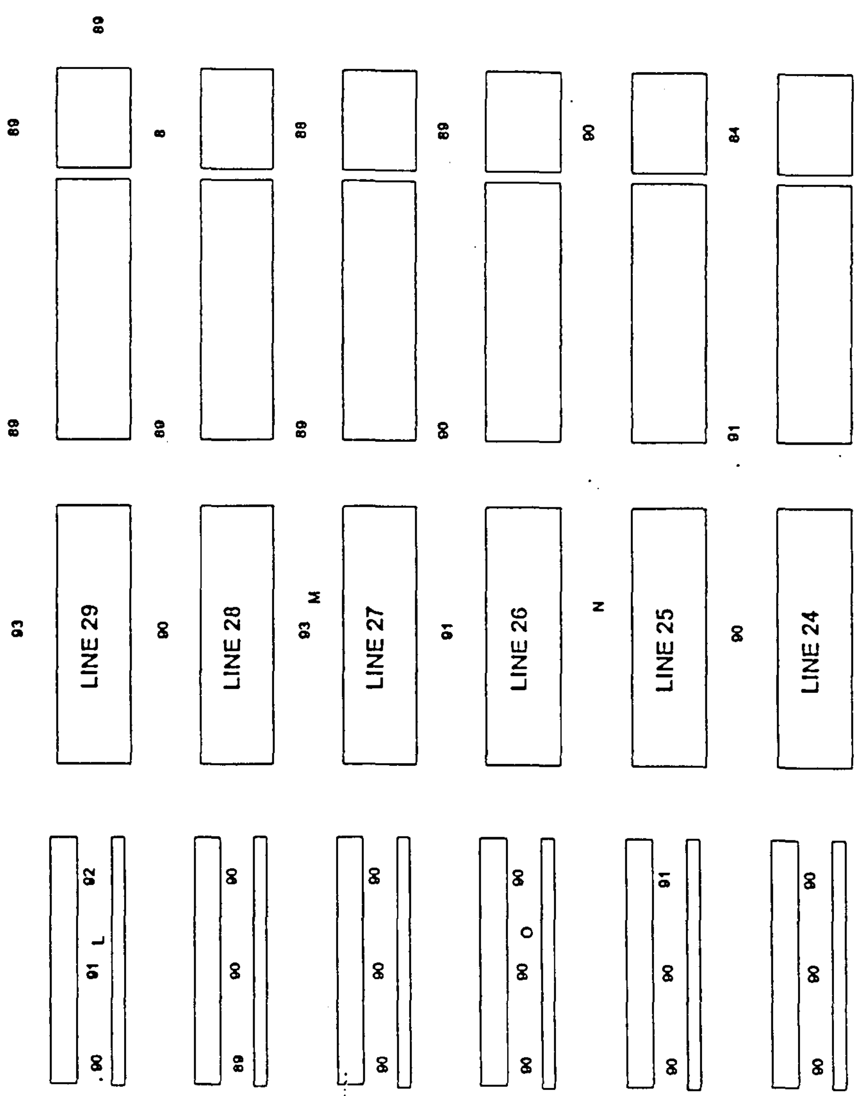


FIGURE 4.1h NOISE LEVELS IN dB(A) AT NEWFORD PARK



4.4.5 Exposures to Noise

Table 4.5 details the level and duration of exposure over 8 hours of certain jobholders, also indicating their tasks

TABLE 4.5 Personal Exposures To Noise dB(A) At Newford Park

JOB	TASK	EXPOSURE		
		Level	Duration (Mins)	$L_{EP,}d$
Extruder Operator	Lines 50 - 54	94	480	94
Extruder Operator	Lines 1 - 22	90	480	90
Extruder Operators	Lines 23 - 29	91	480	91
Electrician	General Duties	87	480	87
Engineer	General Duties	87	480	87
Shift Team Leader	Supervision	90	480	90
QC Assistant	Quality Control	82	480	82
Twister	Twister Operation	90	480	90
Tube Recovery	Tube recovery	89	480	89
Materials Handler	Materials Handling	95	480	95
Lead Hand	Lines 1 - 22	89	480	89
Lead Hand	Lines 23 - 29	92	480	92

4.4.6 Summary of Area Levels of Noise

The level of noise in dB(A) is given for specific areas with details of the source of the noise see table (4.6). These figures are expressed in a range from which it can be seen that QC Room and Team Rooms have a fairly low level at 64 dB(A) and 67 - 79 dB(A) respectively, whilst the area where the Spinneret Lines 13 - 29 are situated has a noise level of 86 - 97 dB(A), see table (4.6).

TABLE 4.6 Summary Of Estimated Exposure To Noise dB(A) At Newford Park

LOCATION	SOURCE	LEVEL dB(A)
Spinneret Lines 1 - 12	Extruders/winders, roller,elevators/pumps	86 - 93
Spinneret Lines 13 - 29	Extruders/winders, roller, elevators/pumps	86 - 97
Slit film Lines 50, 51, 52, 54 and 55	Extruders/winders, Extruders/winders	85 - 92
Slit film Lines 56 and 57	Extruders, rollers, pumps, fans,winders	83 - 91
Multifilament Line 60	Extruders, rollers, pumps, fans, winders	83 - 85
Twisters	Twisters	87 - 91
Tube recovery	Twisters and tuben recovery machine metal-metalimpact	89
Boiler House	Boiler	74 - 82
Team rooms	Spinneret line	67 - 69
Compressor House	Atlas CopCo compressor	82
QC Lab	Spinner and slit film	64
Goods Inward Area	Pumping station	70 - 94

4.5 ST. JAMES WORKS

4.5.1 Manufacturing Process

The main function of the factory is weaving polypropylene. The beaming and the inspection process are relatively quiet operations but these areas open up into the weaving area where there are over 100 Sulzer looms, which are regularly spaced out. The looms are fitted with zero dwell shafts which minimises noise emission.

The weaving area has a low ceiling which is partially glazed. Floors are concrete. The area is reverberant. Hearing protection is mandatory in the factory and warning signs are posted. A choice of hearing protection is provided, however, a large number of people wear disposable plugs.

The thermal bonding/needleweave equipment was operating on the quieter thermal bonding process. The needleweave machines are located inside acoustic enclosures which were of a good construction and design. The doors were closed and had good seals. The walls of one side of the factory, between the process and the nearest houses, were lined with absorptive material. The roof in this area was double skinned. The needleweave was mounted on a purpose-built isolated plinth. Audiometry was reported to be carried out annually.

4.5.2 Shift System

The shift system worked at St. James is as follows:

5 shift system =	1400 to 2200 hrs
	2200 to 0600 hrs
	0600 to 1400 hrs

7 days on with 4-5 off, 2-3 days off during holidays.

*3 shift system

4.5.3 *Population/Jobs Per Shift*

The job titles and numbers in each job per shift can be seen in table (4.7), along with an indication of the hours worked per day, per week and per month.

TABLE 4.7 Population/Jobs Per Shift At St James Works

Job Title	Numbers in Job	Hours/ Day	Hours/ Week	Hours/ Month
Overlookers	5	8	36	144
Labourers	2	8	36	144
Weavers	9	8	36	144
Thermal Bonding/ Needle Weavers*	4	8	36	144
Engineer	1	8	36	144
Beamer	6	8	36	144
Inspector	3	8	36	144

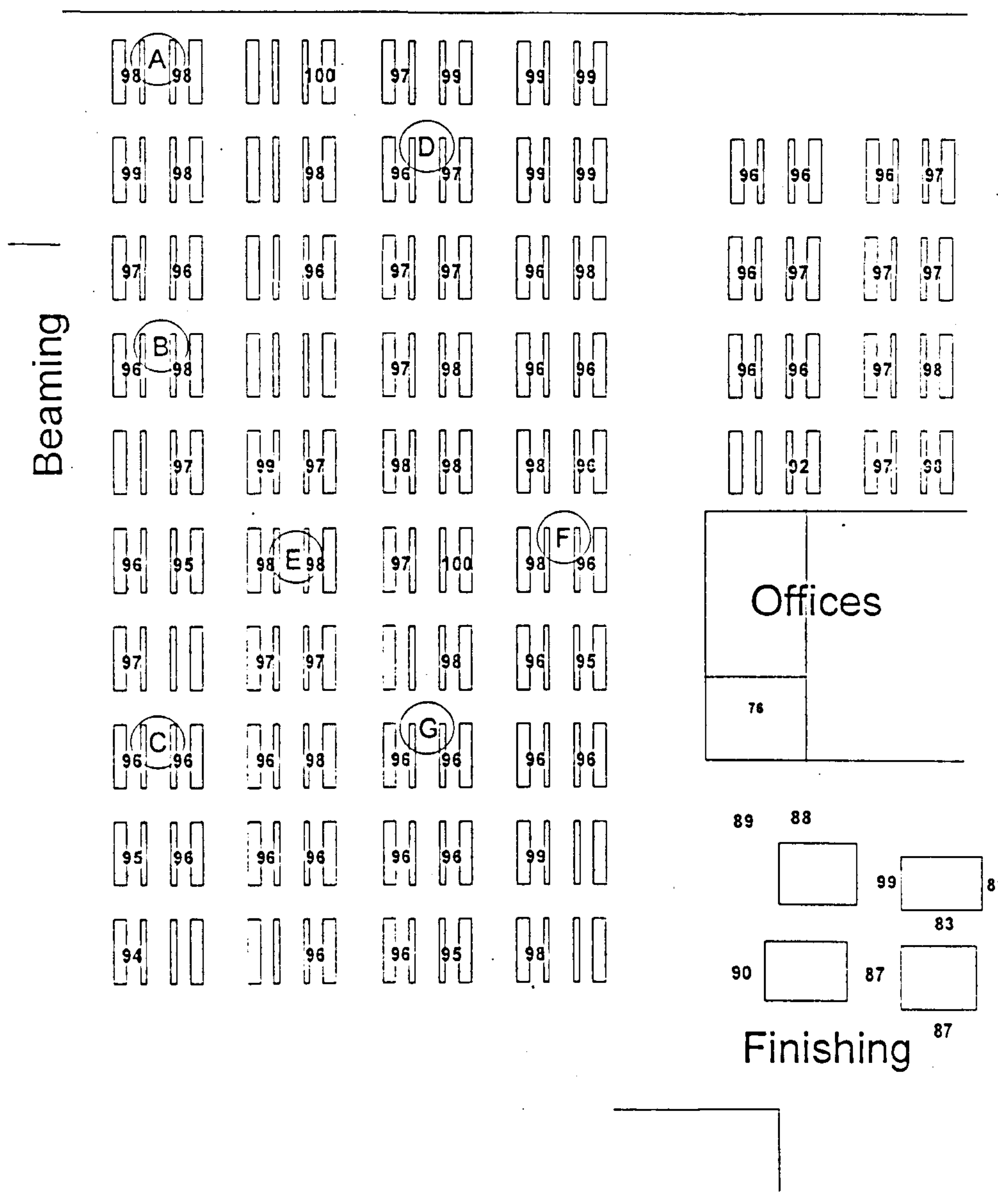
4.5.4 *Exposure in Certain Areas Using Octave Centre Band Frequency*

Table (4.8) details the exposure (in decibels) in specific areas using the octave centre band frequency levels. The exact positions of these areas can be seen in Figure (4.2).

TABLE 4.8 Octave Band And Analysis For St James Works

Octave Centre Band Frequency	Fig.4.2 Pos.A	Fig.4.2 Pos.B	Fig.4.2 Pos.C	Fig.4.2 Pos.D	Fig.4.2 Pos.E	Fig.4.2 Pos.F	Fig.4.2 Pos.G
31.5 Hz	85	89	87	85	85	87	87
63	90	90	91	87	88	93	91
125	89	90	90	88	89	91	91
250	88	89	89	90	89	91	91
500	89	92	91	90	90	91	91
1K	89	92	91	90	89	91	91
2K	89	92	91	90	89	91	91
4K	86	89	87	86	85	90	88
8K	81	82	81	80	78	82	82
16K	75	75	76	70	69	73	75
dB(Lin)	97	99	99	97	97	97	99
dB(a)95	98	96	96	95	96	96	96

FIGURE 4.2 WEAVING AREA NOISE LEVELS IN dB(A) AT ST JAMES WORKS



4.5.5 *Exposure to Noise*

Table (4.9) details the level and duration of exposure of certain jobholders, also indicating their tasks.

TABLE 4.9 Personal Exposure To Noise dB(A) at St James Works

JOB	TASK	EXPOSURE		
		Level	Duration (mins)	$L_{EP}d$
Team Leader	Supervision	94	454	94
Snr. Overlooker	Machine Supervision/ Repairs	96	449	96
Overlookers	Machine Supervision/Repairs	94	452	94
Weavers	Weaving	97	455	97
Team Leader	Beaming	89	470	89
Beamers	Beaming	89	472	89
Materials Handlers	Materials Handling (Labourer)	96	475	96
Team Leader	Inspection	87	470	89
Inspectors	Inspection	91	470	91
Chargehand	Thermal Bonding Equip	85	439	85
Operators	Thermal Bonding Equip	89	441	89
Engineer	Miscellaneous Duties	93	465	93

Area levels of noise in the weaving area were in the range 96 - 100 dB(A). Summary of the above table indicates exposures of shift personnel were in the following ranges

(a) Overlookers 91 < 96 dB(A) $L_{EP}d$

(b) Weavers 94 < 98 " "

(c) Beamers 81 - 89 " "

(d) Materials Handling 93 - 99 " "

(e)	Inspectors	88 < 95	dB(A) $L_{EP}d$
(f)	Thermal bonding	85 - 90	" "
(g)	Engineer	85 - 89	" "

The exposures of workers such as beamers and inspectors arose from the noise from the weaving area. Exposures of operators in the thermal bonding/needleweave area are expected to be higher during needleweaving.

4.5.6 *Summary of Area Levels of Noise*

The level of noise in dB(A) is given for specific areas with details of the source of the noise, see table (4.10). These figures are expressed in a range from which it can be seen that the office and canteen with noise level of 70 and 74 dB(A) respectively is reasonable but the area of the looms/weaving has a significantly higher exposure to noise at a range of 96 ≤ 100 dB(A).

TABLE 4.10 Summary Of Estimated Exposure Of Noise In dB(A) at St James Works

LOCATION	SOURCE	LEVEL dB(A)
Looms	Looms	96 ≤ 100
Beaming	Looms	87 ≤ 89
Inspection	Looms	85 ≤ 93
Thermal Bonding	Looms	79 ≤ 83
Canteen	Looms	≤ 70
Office	Looms	≤ 74

4.6 CANMORE WORKS

4.6.1 Manufacturing Process

At this factory the following processes are carried out:-

(a) Weaving polypropylene

(b) Inspection

(c) Dref spinning

(d) Airtex

In the inspection area relatively quiet jobs are carried out, however, there is high background noise arising from the weaving area. In the weaving area there are 47 looms. The ceiling is moderately low. The area is reverberant. Airtex is an alternative spinning process which produces a fibrous yarn similar to the Dref spinners but the process is inherently quieter.

Hearing protection is mandatory in the factory but not worn in the Finishing area. A choice of hearing protectors is available. Audiometry was reported to be carried out anually.

4.6.2 Shift System

The shift system worked at Canmore Works is as follows.

Shift system	=	1400 to 2200 hrs
		2200 to 0800 hrs
		0800 to 1400 hrs

4.6.3 *Population/Jobs Per Shift*

The job titles and numbers in each job per shift can been seen in table (4.11), along with an indication of the hours worked per day, per week and per month.

TABLE 4.11 Population/Job Per Shift At Canmore Works

Job Title	Numbers in Job	Hours/ Day	Hours/ Week	Hours/ Month
Weavers	8	8	56	143
Technician	3	8	56	143
Materials Handler	1	8	56	143
Malimo Operator	2	8	56	143
Airtex Operators	2	8	56	143
Dref Spinner	8	8	56	143
Materials Handler	2	8	56	143
Finisher	17	8	56	143

4.6.4 *Exposure in Certain Areas Using Octave Centre Band Frequency*

Table (4.12) details the exposure (in decibels) in specific areas using the octave centre band frequency levels. The exact position of these areas can be seen in Figures (4.3a, 4.3b ,4.3c and 4.3d).

TABLE 4.12 Octave Band Analysis For Canmore Works

	LOCATION					
Octave Centre Band Frequency (Hz)	D ref Spinners Fig 4.3b Pos. G	D ref Spinners Fig 4.3b Pos. F	By Looms Fig 4.3c Pos. A	By Looms Fig 4.3c Pos. B & Pos. C	By Airtex Machine Fig 4.3d Pos. C	By Airtex Machine Fig 4.3d Pos. D
31.5	82	79	85	85	78	69
63	89	90	83	84	81	66
125	93	93	86	84	86	67
250	92	92	88	88	87	73
500	92	93	88	89	86	85
1K	93	94	89	89	84	82
2K	93	93	91	91	84	76
4K	95	94	90	91	85	76
8K	89	89	85	85	81	84
SPL (dB) Lin	101	100	97	98	94	90
dB(A)	100	100	96	97	91	88

FIGURE 4.3a PLOT PLAN FOR CANMORE WORKS

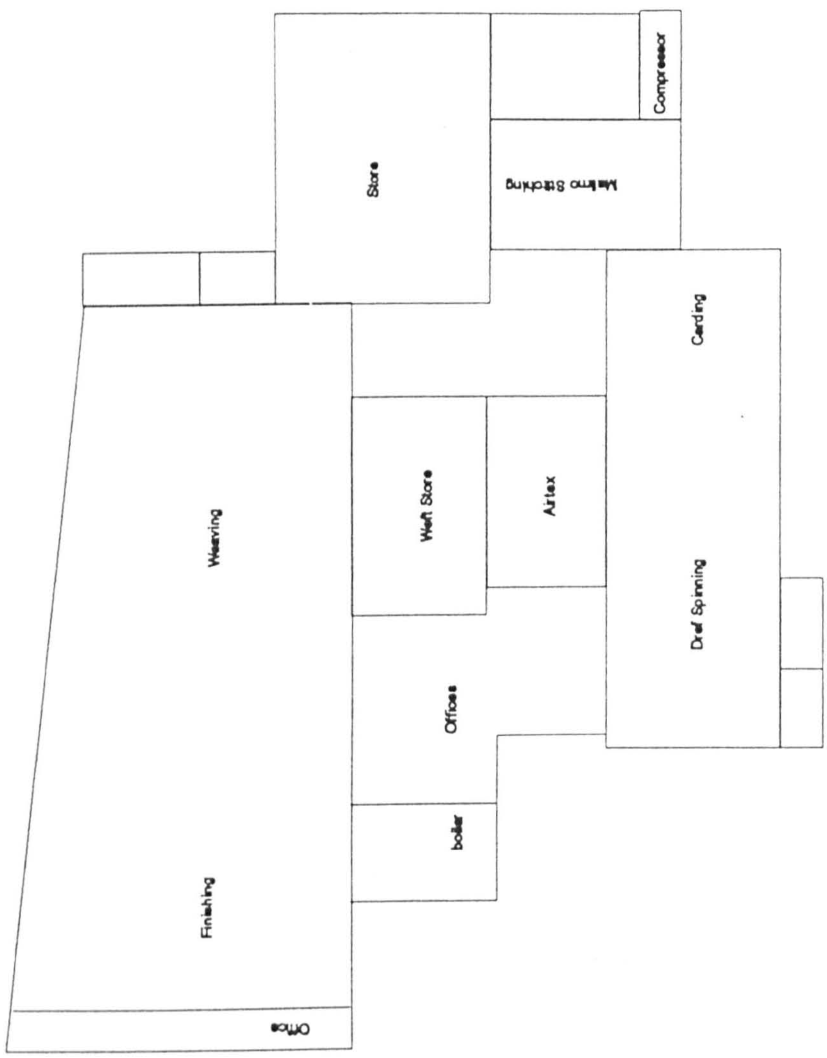


FIGURE 4.3b NOISE LEVELS IN dB(A) AT CANMORE WORKS

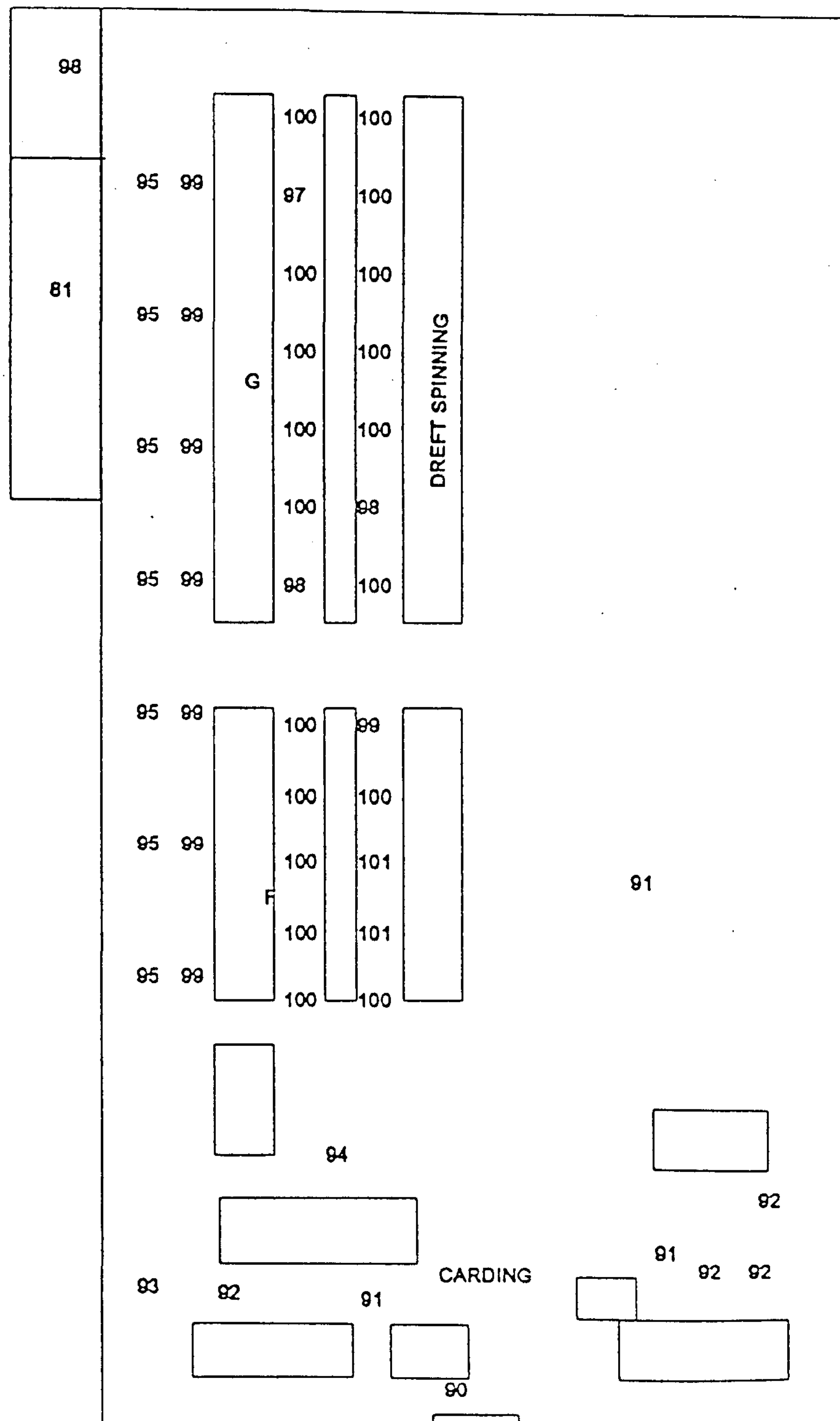


FIGURE 4.3c NOISE LEVELS IN dB(A) AT CANMORE WORKS

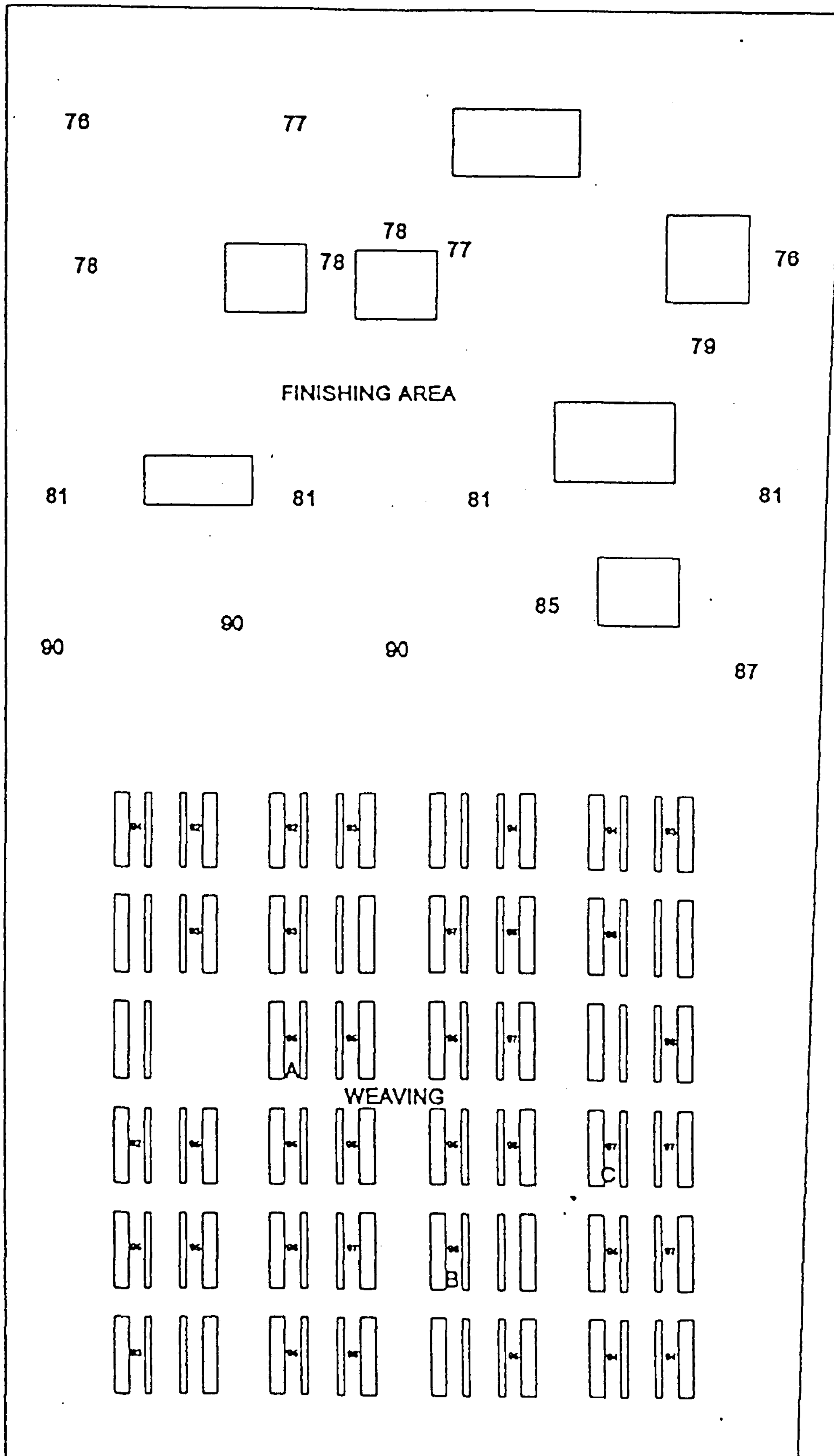
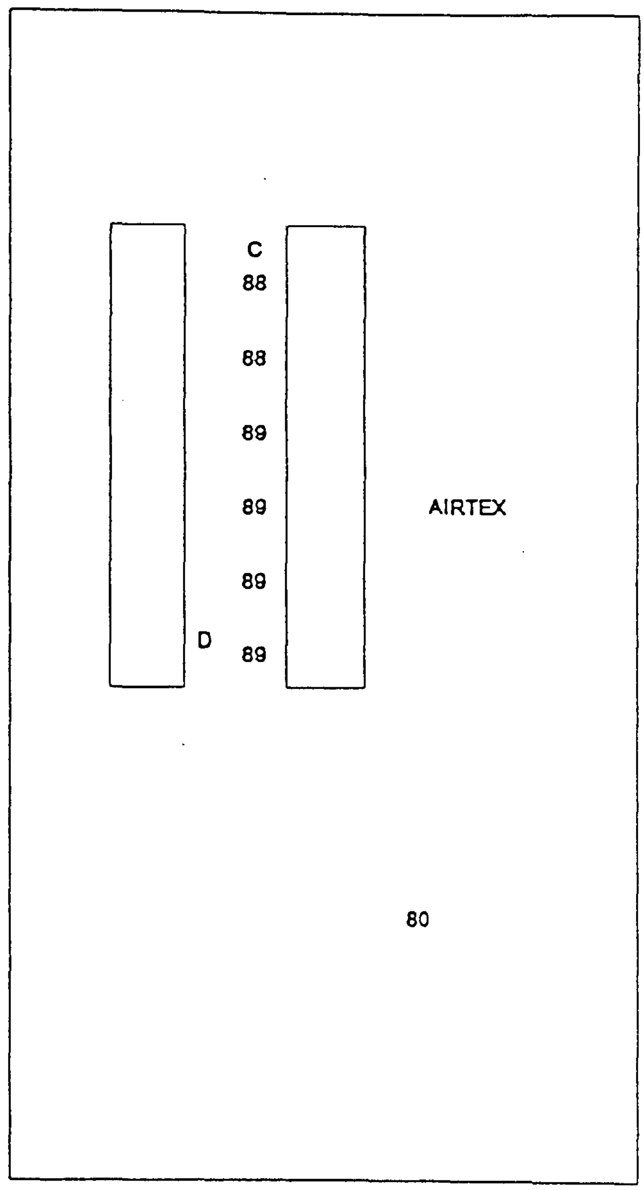


FIGURE 4.3d NOISE LEVELS IN dB(A) AT CANMORE WORKS



4.6.4 Exposures to Noise

The following table (4.13) details the level and duration of exposure of certain jobholders, also indicating their task.

TABLE 4.13 Personal Exposure To Noise dB(A) At Canmore Works

		EXPOSURE		
JOB	**TASK**	**Level**	**Duration (Mins)**	**$L_{EP.}d$**
Weavers	**Weaving**	**95**	**480**	**95**
Technician	**Loom Repair**	**94**	**480**	**94**
Materials Handler	**Materials Movement**	**90**	**480**	**90**
Operators (Airtex)	**Airtex Spinner**	**91**	**457**	**91**
Dref Spinners	**Dref Spinning**	**98**	**480**	**98**
Finishers	**Finishing**	**85**	**348**	**85**

Table (4.13) can be further summarised as the survey of exposure to noise and area levels carried out during the production of a range of products based on polypropylene thread. The results were that exposure of shift personnel was in the following ranges :-

(a) Weaving area $90 \leq 97$ dB(A) $L_{EP}d$

(b) Machine stitching area $84 \leq 87$ dB(A) $L_{EP}d$

(c) Airtex area $88 \leq 91$ dB(A) $L_{EP}d$

(d) Dref spinning area $93 \leq 99$ dB(A) $L_{EP}d$

(e) Finishing area $84 \leq 86$ dB(A) $L_{EP}d$

Exposures recorded by dosimetry were consistent with area noise levels.

4.6.6 *Summary of Area Levels of Noise*

The level of noise in dB(A) is given for specific areas with details of the source of the noise, see table (4.14). These figures are expressed in a range from which it can be seen that at Canmore Works the area most affected by noise is at the location of the Dref Spinners with a noise level of $93 \leq 101$ dB(A).

TABLE 4.14 Summary Of Estimated Exposure Of Noise dB(A) at Canmore Works

LOCATION	SOURCE	LEVEL dB(A)
Between Looms	Looms	$92 \leq 97$
By Dref Spinners	Dref Spinners	$93 \leq 101$
By Cording Machines	Cording Machines/Dref Spinners	$88 \leq 89$
By Airtex Machine	Airtex Machine	$80 \leq 90$
Finishing Area	Looms	$77 \leq 90$

4.7 WALLACE WORKS

4.7.1 Manufacturing Process

Two main processes are carried out at Wallace Works, beaming which is the winding of the polypropylene warp from bobbins on to a roller, and weaving.

There are two winding lines and ninety looms. After weaving, the finished material is inspected and repaired as required. Beaming and inspection are relatively quiet operations but are in the same area as the looms. There is a saw in the inspection area.

The factory has a moderately high ceiling which is partially glazed in order to take advantage of daylight. The floors are concrete, the walls brick and the whole factory is reverberant. The looms are positioned on felt pads on a concrete floor. Looms, when faulty, are either repaired in-situ or parts are removed to the workshop.

Hearing protection is mandatory in the factory and warning signs are posted. A choice of hearing protection is provided. Audiometry was reported to be carried out annually.

4.7.2 Shift System

The shift system worked at Wallace Works is as follows.

Shift system	=	1400 to 2200 hrs
		2200 to 0600 hrs
		0600 to 1400 hrs

7 days on with 4-5 off, 2-3 days off during holidays.

4.7.3 Population/Jobs Per Shift

The job titles and numbers in each job per shift can be seen in table (4.15), along with an indication of the hours worked per day, per week and per month.

TABLE 4.15 Population/Job Per Shift At Wallace Works

Job Title	Numbers in Job	Hours/ Day	Hours/ Week	Hours/ Month
Senior Overlooker	1	8	36	144
Overlooker	3	8	36	144
Material Handler	2	8	36	144
Tier Weaver	10	8	36	144
Lub/Inspector	2	8	36	144
Beamer	4	8	36	144
Electrician	1	8	36	144
Maintenance Engineer	2	8	36	144

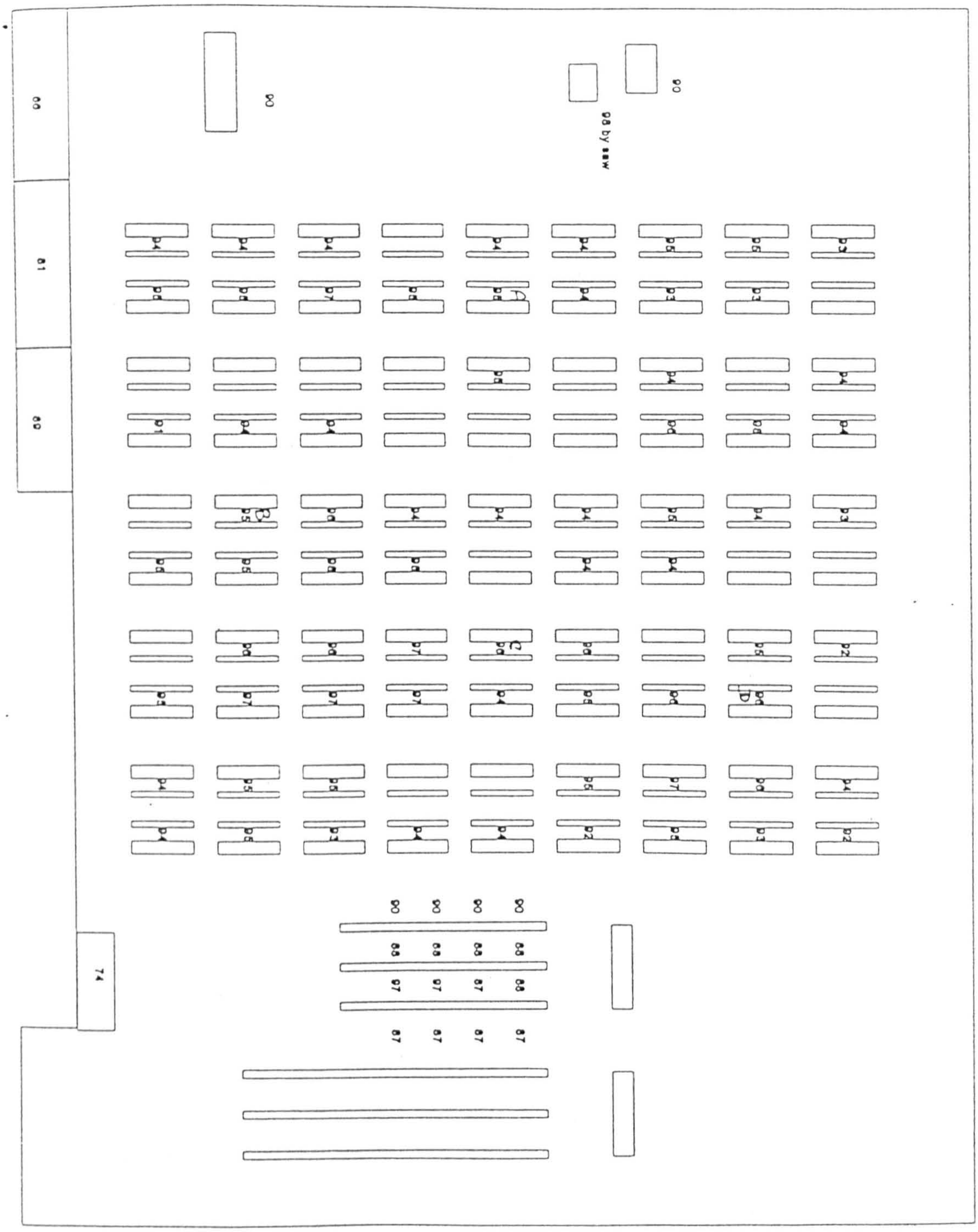
4.7.4 *Exposure in Certain Areas Using Octave Centre Band Frequency*

Table (4.16) details the exposure (in decibels) in specific areas using the octave centre band frequency levels. The exact position of these areas can be seen in Figure (4.4).

TABLE 4.16 Octave Band Of Analysis At Wallace Works

Octave Centre Band Frequency (Hz)	Betwen Sulzer Looms			
	Fig. 4.4 Pos. A	Fig. 4.4 Pos. B	Fig. 4.4 Pos. C	Fig. 4.4 Pos. D
31.5	86	83	83	83
63	99	89	95	89
125	94	88	92	87
250	90	88	91	85
500	90	89	90	90
1K	90	89	90	90
2K	89	89	90	90
4K	86	85	88	88
8K	81	80	82	82
dB(Lin)	101	97	99	98
SPL dB(A)	95	95	96	96

FIGURE 4.4 NOISE LEVELS IN dB(A) AT WALLACE WORKS



4.7.5 Exposure To Noise

Table (4.17) details the level of duration of exposure among certain jobholders, also indicating their tasks.

TABLE 4.17 Personal Exposure To Noise dB(A) At Wallace Works

JOB	TASK	EXPOSURE		
		Level	Duration (Mins)	$L_{EP.}d$
Weavers	Weaving	97	450	97
Mainteannce	Genral Duties	86	450	86
Materials Handler	Materials Movement	95	450	95
Lab/Inspector	Inspection	90	450	90
Inspector	Inspection	92	450	92
Finisher	Finishing	85	450	85
Beamer	Beaming	87	453	87

Table (4.17) can be summarised as the survey of exposures to noise and area levels carried out at Wallace Works of Don & Low during the production of a range of products based on polypropylene thread as follows:

(a) Weaving Area (loom area) 92-97 dB(A) $L_{EP}d$

(b) Finishing area 84-86 dB(A) $L_{EP}d$

(c) Beaming area 85-89 dB(A) $L_{EP}d$

4.7.6 *Summary of Area Levels of Noise*

The level of noise in dB(A) is given for specific areas with details of the source of the noise, see table (4.18). These figures are expressed in a range from which it can been seen that in the beaming area, inspection area and between the Sulzer looms a significant level of exposure to noise is apparent with the ranges being 87 to 90, 90 to 98 and 92 to 97 dB(A) respectively.

TABLE 4.18 Personal Exposure To Noise dB(A) At Wallace Works

POSITION	SOURCE	LEVEL dB(A)
Between Sulzer Looms	Looms	$92 \leq 97$
By Saw Inspection Area	Saw & Looms	$90 \leq 98$
Beaming Area	Looms	$87 \leq 89$
Sulzer Repair Shop	Looms	≤ 69
Maintenance Shop	Looms	≤ 81
Rest Area	Looms	≤ 74
QC Laboratory	Looms	≤ 66

CHAPTER 5

DEMOGRAPHIC DISTRIBUTION OF EMPLOYEES AT DON & LOW

5.1 Introduction

Actual Statistics Of Employees From Don & Low According To Job\ Categories (Noise Levels) have been divided into four groups, see table (5.1):

TABLE 5.1 Total Number of employees working at Don & Low

Group	Exposure/Job	No. of Employees
A	≥95dB	282
B	90<95 dB	175
C	85<90 dB	148
D	<85dB	141
Total		746

All groups were divided according to the level of noise the jobholders are exposed to as listed below:

Group A

This group covers the following jobs:

Yam/Dref Operator, Weaver, Material Handler, Dref Spinners, Weaver Overlookers

Group B

This group covers the following jobs:

Team Leader, Shift Team Leader, Senior Overlooker, Inspector, Operator (Airtex), Warehouseman, Extrusion Operator, Slit Film Operator, Twister, Technician

Group C

This group covers the following jobs:

Beamer, Maintenance, Electrician, Engineer, Tube Recovery, Finisher, Sideloader, Re-rolling/Brushing, Production Co-ordinator, Training/Safety Co-ordinator, Thermal Bonding,

Group D *(Control Group)*

This group received less than 70 dB in all cases as follows:

Administration Assistant, Die Maintenance Lab, Development, Supervisor, General Assistant, Cleaner, Component Restorer, Technical Supervisor, Secretary, Works Manager, Storeman, Clerical Assistant, Receptionist. Other office workers

5.2 The response of the employees to the study

In all job categories the participators of employees in all job categories were 394, see table (5.2). The highest participation in category job were ≥95dB (35.8%) and the lowest response was in group 85 <90dB (19%).

TABLE 5.2

The Distribution of Participators Regarding Exposure/Job

Categories	Frequency	Percent	Sum Percent
≥95dB	141	35.8	35.8
90<95dB	84	21.3	57.1
85<90dB	75	19.0	76.1
<85dB	94	23.9	100.0
Total	394	100.0	

The fractional response from the total population of Don & Low employees is listed below See table (5.3):

TABLE 5.3

Particpators to the Questionnaire of the Employees Regarding Exposure/Job from the Total Employees

Categories	Frequency of Response	Total No employees	Percentage of Response
≥95dB	141	282	50%
90 < 95dB	84	175	48%
85 < 90dB	75	148	50%
<85dB	94	141	66.7%
Total	394	764	51.6%

The mean average number of years in service for the 394 employees is 10.32, with a standard deviation of 4.78. For categories ≥95dB the mean is 9.46, with a standard deviation of 3.61. 141 employees are represented in that category. For category 90<95dB the mean is 10.68, with a standard deviation of 3.64, for a sample of 84 employees in that category. For category 85<90dB the mean is 10.31 with a standard deviation of 4.05, for a sample of 75 employees. Lastly, for category <85dB the mean is 11.32 with a standard deviation of 7.05, for 94 employees.

With regard to sex, the response was as shown in the table (5.4):

TABLE 5.4 Participators of Employees Regarding Sex to the Questionnaire

Sex	Frequency	Percent	Sum Percent
Male	263	66.8	66.8
Female	131	33.2	100.0
Total:	394	100.0	

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TABLE 5.6 Female Probands With Regard To Job Categories/Age Groups

Female Age Group	Exposure/Job					
	<85dB	85-<90dB	90-<95dB	95+dB	Total	%
<25 years	7	0	0	4	11	8.4
≥25 and < 35 years	14	1	0	23	37	28.2
≥35 and <45 years	10	0	1	16	27	20.6
≥45 and <55 years	9	2	3	22	36	27.5
≥55 years	4	0	1	15	20	15.3
Total	44	3	5	79	131	100.00
%	33.6	2.3	3.8	60.3	100.00	

TABLE 5.7 Male Probands With Regard To Job Categories/Age Groups

Male Age Group	Exposure/Job					
	<85dB	85-<90dB	90-<95dB	95+dB	Total	%
<25 years	5	7	2	2	16	6.1
≥25 and < 35 years	17	11	20	26	74	28.1
≥35 and <45 years	13	21	19	10	63	24.0
≥45 and <55 years	11	21	28	16	76	28.9
≥55 years	4	12	10	8	34	12.9
Total	50	72	79	62	263	100
%	19	27.4	30.0	23.6	100.00	

CHAPTER 6

AUDIOMETRIC TEST RESULTS

6.1 Equipment

Kamplex Basic Diagnostic Audiometer Model AD12

(Equipment used generally for this study)

• economic diagnostic portable audiometer

• 9 frequencies from 250 to 8000Hz

• Narrow band masking

• Mains/battery powered

6.2 General Description

Model AD12 is a mains/battery portable diagnostic audiometer for pure tone air and bone conduction threshold measurements. It is supplied complete with calibrated TDH 30 Headset, Bone Conductor, Carrying and Protective Storage Case, built-in mains unit and Battery Unit. Audiocups and insert masking phone are optional extras. All accessories fit into the storage compartment of the carrying case.

Mercury Audiometer (ASRA 2001)

(equipment used as backup throughout study)

• Performs automatic or manual threshold hearing tests

• Presents results on computer screen

• Runs on IBM compatible computers

• Allows you to view employee information and allows alterations

• Uses Random & Stenger tests

• Four frequencies included in program.

The menu parameters are:

1. Default response time (default: 1500ms - range: 0-4000)

2. Tone length (defualt: 1000ms - range: 0-4000)

3. Default: 1 - range 0-4)

4. Colours used for printing (default: 716 - range 111-777)

6.3 Methodology

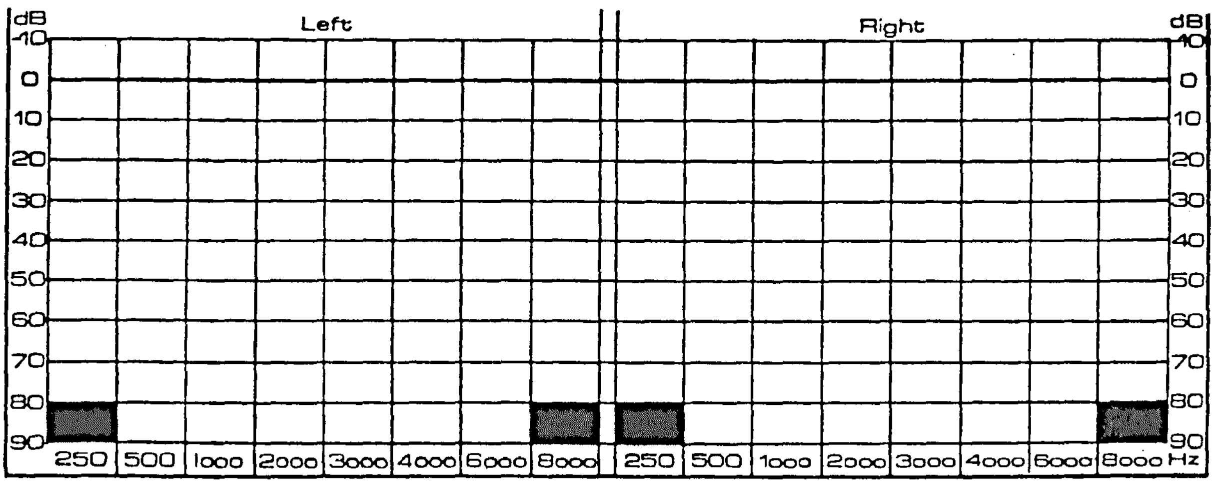
The methodology for the Audiogram Assessment is similar to the method used by the East of Scotland Occupational Health Service, 1985 [72] which was developed by Bryan and Tempest in 1977. (East of Scotland Occupational Health Service Limited,1984)[73]. The method is based on the groupings of results from zero to six (0-Vi), where group zero has no handicap in hearing, to group VI having a total deafness, as described in table (6.1).

TABLE 6.1 The Average Hearing at These Frequencies is Used By Tempest to Produce A Number of Handicap Groups

Average Hearing Level at 500 Hz 1 & 2 kHz (dB)	High Frequency Hearing Level at 4 and/or 6 kHz (dB)	Group	Brief Description Of Handicap
0-25	Less than 25	0	No handicap
0-25	25 or more	I	Slight handicap in noise
25-40	NA	II	Slight handicap for faint speech
40-55	NA	III	Mild handicap, affects normal speech
55-70	NA	IV	Marked handicap, affects loud speech
70-90	NA	V	Severe Handicap, affects amplified speech
More than 90	NA	VI	Total deafness

The audiogram Fig (6.1), where the result can be recorded for the right and the left ears.

FIGURE 6.1: The Audiogram



The hearing loss (in decibels) is marked on the Y-axis and the sound frequency (in Hertz) is on the X-axis.

The results of the experiment are recorded on the audiogram grid. To interpret the results on the audiogram, a transparent overlay is placed over the audiogram and the results of the hearing are then classified into groups. (See Appendix 1)

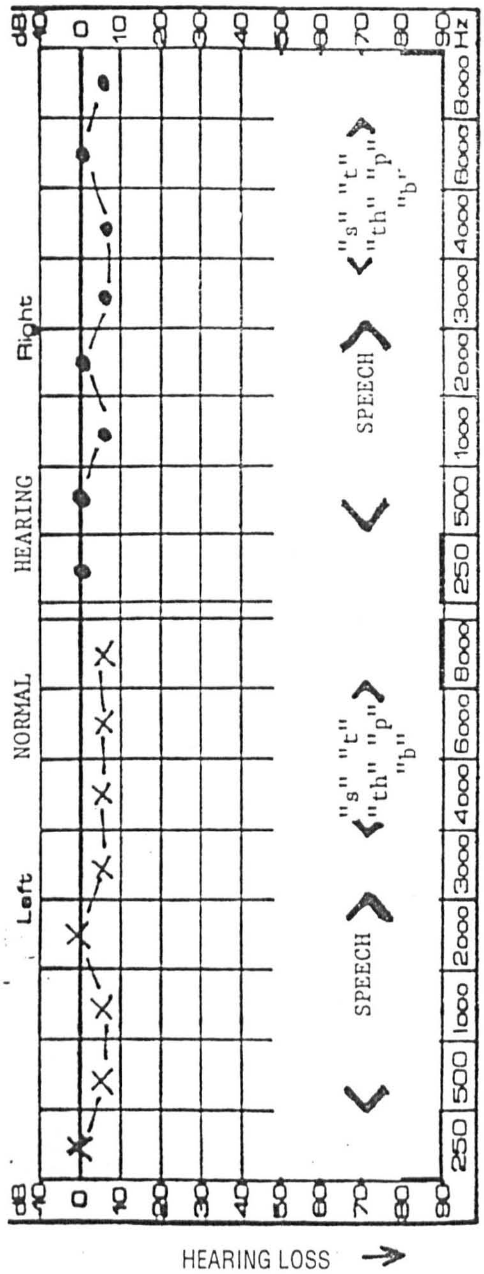
The transparent overlay grid is similar to the audiogram grid except it has two additional horizontal columns (stratified from zero to v and 0 to I).

The horizontal columns 0 to V represents the 1000-2000 frequencies on the X-axis, while the 0-1 column represents the 4000-6000 frequences on the X-axis.

Hearing depends upon:

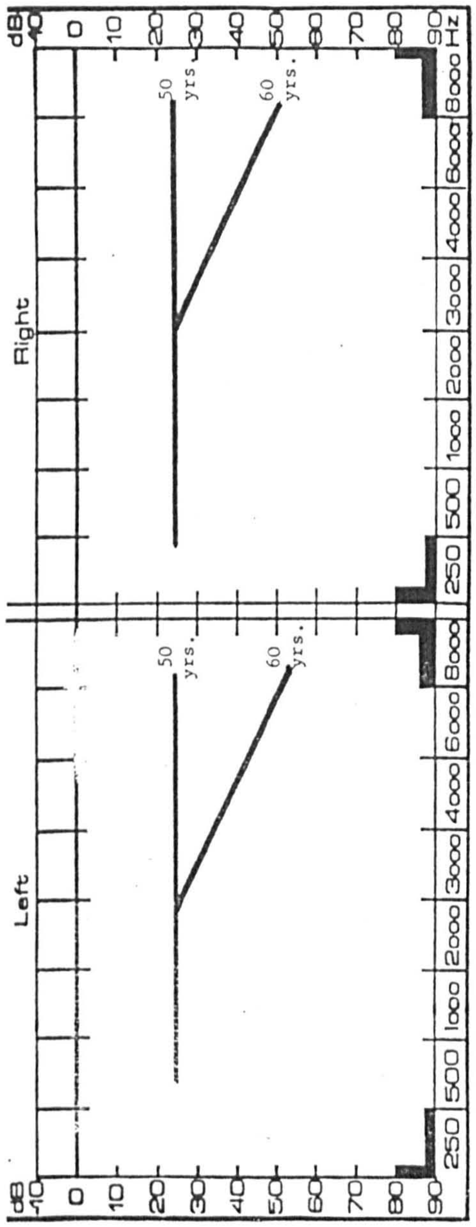
1. Hearing low frequencies in speech.
2. The 4-6 kHz represent high frequencies - for music and some sounds such as 's', 't', 'th', 'p' and 'b'. See Fig (6.2) (East of Scotland Occupational Health Service Ltd, 1985)[72].

FIGURE 6.2: Hearing Sound Distributed With Frequencies



The Fig (6.3) shows Hearing Assessment for High Frequency Hearing Loss Due to Age. You will note that there is no difference up to age 50, but after age 60 there is a slight change in the high frequencies according to the East of Scotland Occupational Health Service Ltd graphs (East fo Scotland Occupational Health Service Ltd, 1985)[72].

FIGURE 6.3: Hearing Loss From Age Alone



6.4. Audiometric Results

By running Chi-Square tests, the results of the audiometric survey for males and females show no difference in class of hearing 0, I, II, whereas the classes III & IV showed differences which are statistically significant ($p>0.05$). On the other hand the reported number in class three is only 3 cases and class IV, 5 cases between the male. No more cases had been reported in class V and VI. These results have been taken disregarding the job categories. Table (6.2) show the numbers in each class of hearing less by sex:

TABLE 6.2: Distribution of Class of Hearing By Sex

Sex	Class					Total
	0	I	II	III	IV	
Male	164	84	7	3	5	263 (66.8%)
Female	95	27	9	0	0	131 (33.2%)
Column Total	259	111	16	3	5	394
Perc Total	65.7	28.2	4.1	.8	1.3	100.0%

When classifying job categories into class of hearing, using the same method as used before (Chi-Square tests), significant results were obtained with p value less than .00002. To understand the significance of the results more investigations were performed and described in this chapter. Table (6.3) relates the class of hearing less of employees to their job categories.

TABLE 6.3: Distributiion of class of Hearing According to Job Categories

Job Categories	Class					
	0	I	II	III	IV	Total
≥95 dB (35.8%)	86	41	10	3	1	141
90<95dB (21.3%)	47	34	2	0	1	84
85<90dB (19.0%)	42	28	3	0	2	75
<85dB (23.9%)	84	8	1	0	1	94
Column	259	111	16	3	5	394
Perc Total	66	28	4	1	1	100.0

Differences in mean hearing levels between the male participants exposed to gunfire and those not exposed were clearly apparent and varied between 9-16dB for the frequencies at 3000, 4000 and 6000Hz. There were no significant differences in female hearing threshold levels. These changes in male hearing are equivalent to the effect of an occupational exposure of 89dB for 20 years.
(Johnson and Riffle, 1982)[74].

The relationship of job categories and working time with class of hearing during Don & Low study has shown a significant result only with employees who worked 15 years and over. On the other hand all the results show that people who worked in a noisy environment 85dB and over seemed to have difficulty in hearing.

From the investigation of the audiometric results, and table one, for people who worked less than one year in a noisy environment there were no reported cases in class II or over. Two cases of employees who worked in 85-<90dB were categorised in class I. The rest of the employees have no difficulty in hearing, see Table (6.4).

TABLE 6.4: Distribution of Classes of Hearing With Regard To Job Categories For Employees With Less Than One Year's Service

	Class		Row
Jop Category	**0**	**I**	**Total**
≥95dB	**2**	**0**	**2**
85<90dB	**1**	**2**	**3**
<85dB	**5**	**0**	**5**
Total	**8**	**2**	**10**

Workers who worked for over one year but less than five years showed no statistically significant results ($p < 0.57$). Even though employees who worked in noisy environments reported a higher proportion in class 1 and 111. The total number in this group (41 in all categories) was not sufficient to yield statistically significant results. Table (6.5) shows the distribution of job categories of hearing over that period of time.

TABLE 6.5: Distribution of Class of Hearing With Regard to Job Categories For Employees With Less than 5 Year's Service

Job Category	Class			Row Total
	0	I	III	
≥95dB	14	0	1	15
90<95dB	5	1	0	6
85<90dB	4	1	0	5
<85dB	14	1	0	15
Total	37	3	1	41

Employees who worked in the time period from 5 to less than 10 years again showed no statistically significant differences in classes of hearing ($p = >0.87$). Although more people who worked in a noisy environment over 85dB reported more cases in the classes of hearing I, II, III, and IV. About 30% of the total workers in that category suffered slight difficulty in hearing. They are reported in class I. The same situation pertains between workers in category 90<95dB and category 85<90dB. Table (6.6) shows the distribution of class of hearing against job category for that period of time.

TABLE 6.6: Distribution of Class of Hearing With Regard to Job Categories For Employees With Less Than 10 Year's Service

Job Category	Class					Row Total
	0	I	II	III	IV	
≥95dB	36	14	1	1	I	53
90<95dB	17	6	0	0	0	23
85<90dB	12	5	0	0	0	17
<85dB	17	2	1	0	0	20
Column Total	82	27	2	I	I	113

Employees who worked from 10 than <15 years have shown no significant results again (p>0.082). This result appeared because 3 out of the 21 employees in job category <85dB reported difficulty in hearing in Class I. Unfortunately more than 50% of employees in job categories >85dB reported difficulty in hearing in Class I, II, III & IV . See Table 6.7.

TABLE 6.7: Distribution of Class of Hearing With Regard to Job Categories For Employees With Less Than 15 Year's Service

Job Category	Class					Row Total
	0	I	II	III	IV	
≥95dB	31	24	9	1	0	65
90<95dB	21	20	2	0	1	44
85<90dB	22	18	3	0	2	45
<85dB	18	3	0	0	0	21
Col Total	92	65	14	1	3	175

A significant result with a p value of .04 has been obtained for employees who work in the time period from 15 to less than 20 years. This is because more workers in a noisy environment have reported difficulties of hearing than have those workers who do not. For example, of employees in categories 90<95dB, six are reported in class I and only four in class 0 compared with those who worked in less than 85dB. Only two reported difficulties out of 21 employees, see Table (6.8).

TABLE 6.8: Distribution of Class of Hearing With Regard To Job Categories For Employees With From 15 Years to 20 Year's Service

Job Category	Class			Row Total
	0	I	IV	
≥95dB	3	3	0	6
90<95dB	4	6	0	10
85<90dB	3	1	0	4
<85dB	19	1	1	21
Column Total	29	11	1	41

A statistically significant result (p<0.013) was obtained for employees with over 20 year's service . That is because a few of them worked over a prolonged period of time. Only 14 out of 394 employees worked for this length of time. Thereafter two employees who worked in areas over 85dB reported in class I compared with 12 employees who worked in ≤85dB only one of whom reported in class I and the rest in class O,see Table (6.9).

TABLE 6.9: Distribution of Class of Hearing With Regard to Job Categories For Employees With Over 20 Year's Service

Job Category	Class		Row Total
	0	I	
90<95dB	0	1	1
85<90dB	0	1	1
<85dB	11	1	12
Column Total	11	1	14

Aging and its effects upon hearing remain a major problem. Although mass data can identify the changes attributed to age, individual differences make it extremely difficult to determine whether audiometric changes are the result of aging, noise exposure, or some other factor (Francis I Catline, 1986)[20].

Randomly selected 49 full-time dairy farmers from an established cohort were used in a study. Medical and occupational histories were taken and standard audiometric testing done on forty six males (94%) and three females (6%) with a mean age of 43.5 ($\pm$13) years and an average of ($\pm$14) years in farming. No association could be found between hearing loss and previous ear infection (May, Marvel, Regan, Marvel and Patt, 1990)[75].

The relationships betwen age, exposure to noise and hearing loss have been investigated.

In job categories with noise level $\leq$95dB, with mean of age 41.23, a statistically significant result ($p< 0.001$) is shown for different ages and the older the workers the greater the hearing difficulties. For example, employees with age less than 25 years had reported no difficulties at all, but of those with age over 55 more than 78% reported hearing difficulties is apparent at intermidiate ages. Growth in hearing difficulties, see Table (6.10).

Table 6.10 Distribution for Class of Hearing According to Age Groups With Regard to Job Categories ≥95dB

Class of Hearing	Age Group in Years					
	<25	25<34	35<44	45<54	≥55	TOTAL
0	6	37	22	16	5	86
I	0	10	3	18	10	41
II	0	0	1	4	5	10
III	0	1	0	0	2	3
IV	0	0	0	0	1	1
Col Total	6	48	26	38	23	141

In workers in job categories 90≤85dB who had a mean age of 42.85 there was a clear relationship between hearing loss and age. The older the employees the more hearing difficulties were reported, even though age group <25 may affect the results because only 2 employees are in that age group. For ages over 45 years, more difficulties in hearing occurred than in any other group, see Table (6.11).

TABLE 6.11: Distribution for Class of Hearing According to Age Groups With Regard to Job Categories 90<95dB

Class of Hearing	Age Group by Years					
	<25	25<34	35<44	45<54	≥55	Total
0	2	16	14	13	2	47
I	0	4	5	16	9	34
II	0	0	0	2	0	2
IV	0	0	1	0	0	1
Column Total	2	20	20	31	11	84

In job categories to 85<90dB with mean age of 42.16 the result was statistically significant ($p < 0.01$). That is because employees aged over 45 years reported difficulties in hearing more than any other group. For example over 60% in the age group 45<55 years had slight difficulty according to classification of hearing (class I), and in ages over 55 years around 67% reported difficulty in hearing, four of them in class I, two in class II, and two in class IV. On the other hand in the middle aged and younger group there are some reported cases showing diffi culty in hearing. The percentage is lower than in the older age groups, and no more than 42% reported with hearing difficulties. All of those employees in these categories reported in class I except one case in class II, see Table (6.12).

TABLE 6.12: Distribution for Class of Hearing According to Age Groups With Regard to Job Categories 85<90dB

Class of Hearing	Age Group in Years					Total
	<25	25<34	35<44	45<54	≥55	
0	4	10	15	9	4	42
I	3	2	5	14	4	28
II	0	0	1	0	2	3
IV	0	0	0	0	2	2
ColTotal	7	12	21	23	12	75

In job category <85dB with means of 38.7 years a statistically significant result (p0.046) which concludes age is a major factor. Table 6.13 indicates age is associated with hearing loss the older the employee, eg age >55 reported 3 cases in Class I out of 8 employees, meanwhile younger workers (<25) have reported no difficulty in hearing at all

TABLE 6.13: Distribution for Class of Hearing According to Age Groups With Regard to Job Categories <85dB

Class of	Age Group in Years					Row
Hearing	<25	25<34	35<44	45<54	≥55	Total
0	12	29	22	16	5	84
I	0	1	0	4	3	8
II	0	1	0	0	0	1
IV	0	0	1	0	0	1
Col Total	12	31	23	20	8	94

CHAPTER 7

METHODOLOGY OF STUDY OF QUESTIONNAIRE AND DESIGN

7.1 Questionnaire Design

To collect the information needed to carry out the survey of the noise and to measure the relationship between noise as agent factor with workers as host factors. A questionnaire was introduced personally to each worker with an explanation to clarify the inforfmation required from it. This quetionnaire was divided into ten parts (see Appendix 2)

1. *Personal details*
2. *Residential area*
3. *Job details*
4. *Hearing difficulties*
5. *Other sources of noise which may affect hearing*
6. *History of hearing/ear problems*
7. *Other health problems with regard to noise*
8. *Industrial accidents related to work environment*
9. *Measurement of awareness of Health & Safety*
10. *Measurement of psychological reactions to workplace*

Each employee had to sign the questionnaire to allow access to audiometry test results.

From this questionnaire the basic information required from the employees was looked at to assess all problems related to hearing and general health.

Part 1

Out of the personal details the employees have been divided according to their sex, age and job groups, as presented in Chapter 5.

Part 2

All workers from their response to the questionnaire live nearby the site within a short ditance in quiet cities/towns such as Forfar and Perth. Those towns being classified as quiet areas. As this is a general response it can now be eliminated from the study.

Part 3

The history details of the employees and if they have worked in a noisy environment over a number of years, was used in the statistical analyses where necessary.

Part 4

In this part we assessed the hearing impairments and matched this with the actual auiometric tests and also to find out from the employees themselves how they judged their hearing.

Part 5

Part 5 was used to exclude those employees who were frequently exposed to other sources of noise such as gunfire, explosions and leisure activities frequently which may also affect the hearing.

Part 6

From part 6 information was collected about the history of hearing and ear problems of employees with regard to their job categories, age and sex and number of years in service etc and the relationship between these factors and working/environmental noise.

Part 7

It is known noise may cause other health problems besides hearing difficulties. In this part we looked at sleep disturbance, annoyance, blood pressure, smoking behaviour.

Part 8

Noise may also interfere with concentration causing industrial accidents. The response to his part was not satisfactory in the first instance because the employees felt too insecure to give detailed information on this subject. On the other hand a second questionnaire distributed to employees with ano nymity, produced better results.

Part 9

Part 9 was used to measure awareness of the employees with regard to their working environment and also to relate the frequency of accidents to any safety training given to employees.

Part 10

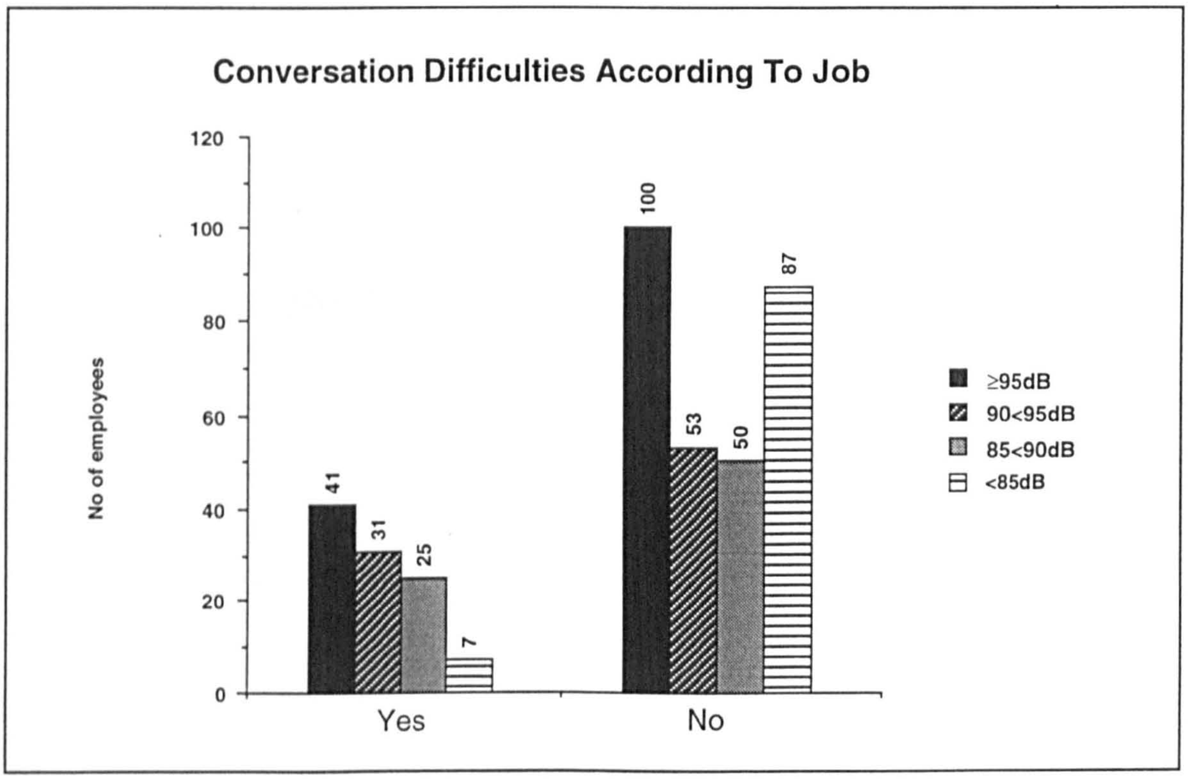
This section was used to relate preference to shifts worked, frequency of breaks and comfort of surroundings to the frequency of industrial accidents.

7.2 HEARING DIFFICUTIES ACCORDING TO THE QUESTIONNAIRE RESULTS

In *Part 4* of the questionnaire an attempt was made to relate the audiometric results with the workers own perception of their hearing as revealed by the questionnaire.

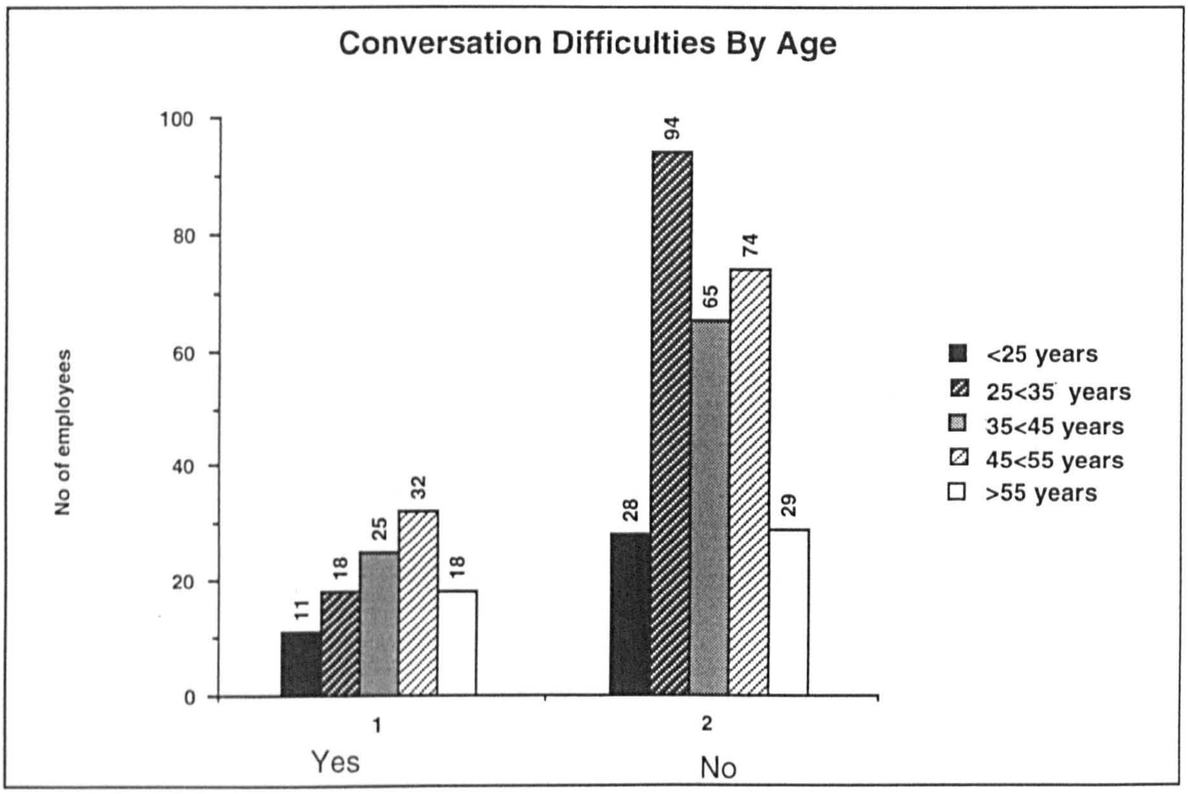
In *question 1* in *part 4* the result was statistically significant ($p<0.001$) and that shows the more you are exposed to higher frequencies the more difficulty the workers have in following a conversation if there is background noise, eg TV, radio, children playing etc (Fig 7.1) presents this distribution.

FIGURE 7.1



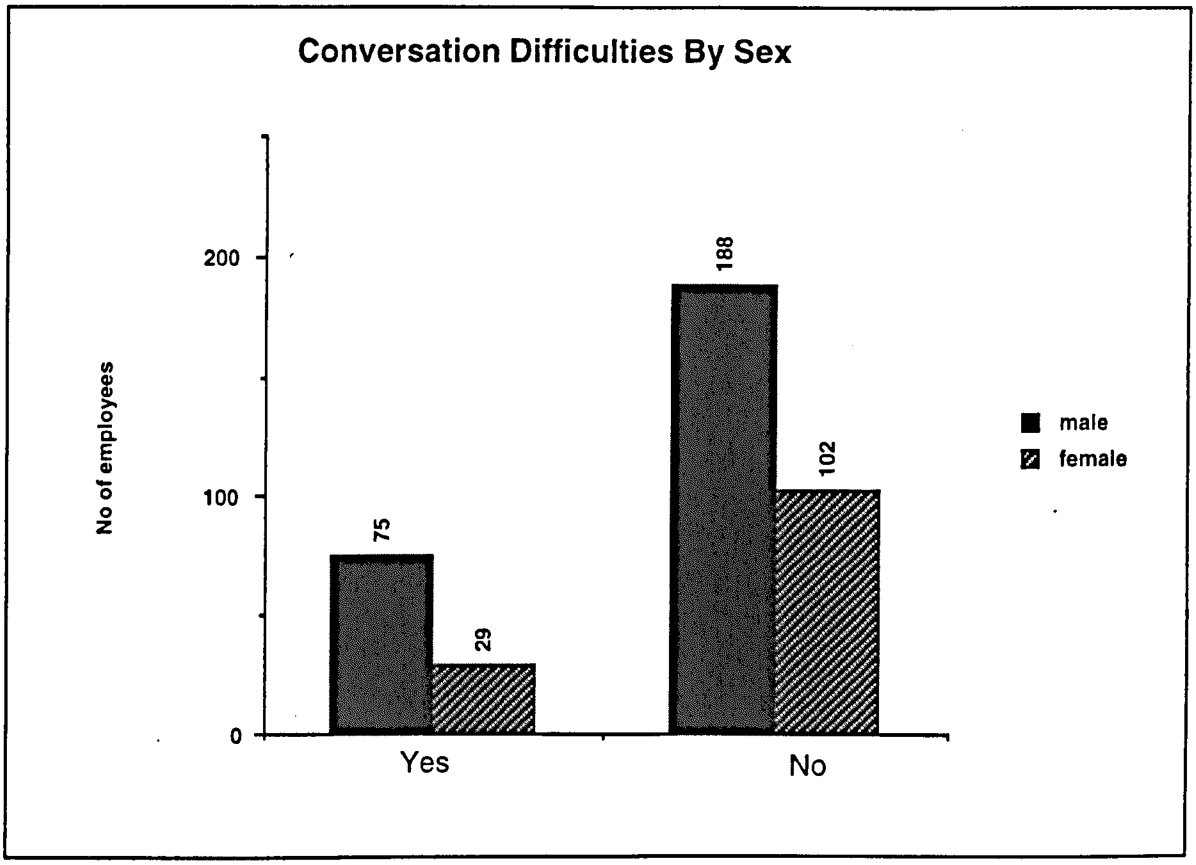
More people reported they had no problem hearing a conversation in the middle age group eg. 16% older than 25 years. On the other hand, more of the older and the younger groups reported more difficulty with 38.3% of the group older than 55 years and 28.2% for the group younger than 25 year (see Fig 7.2).

FIGURE 7.2



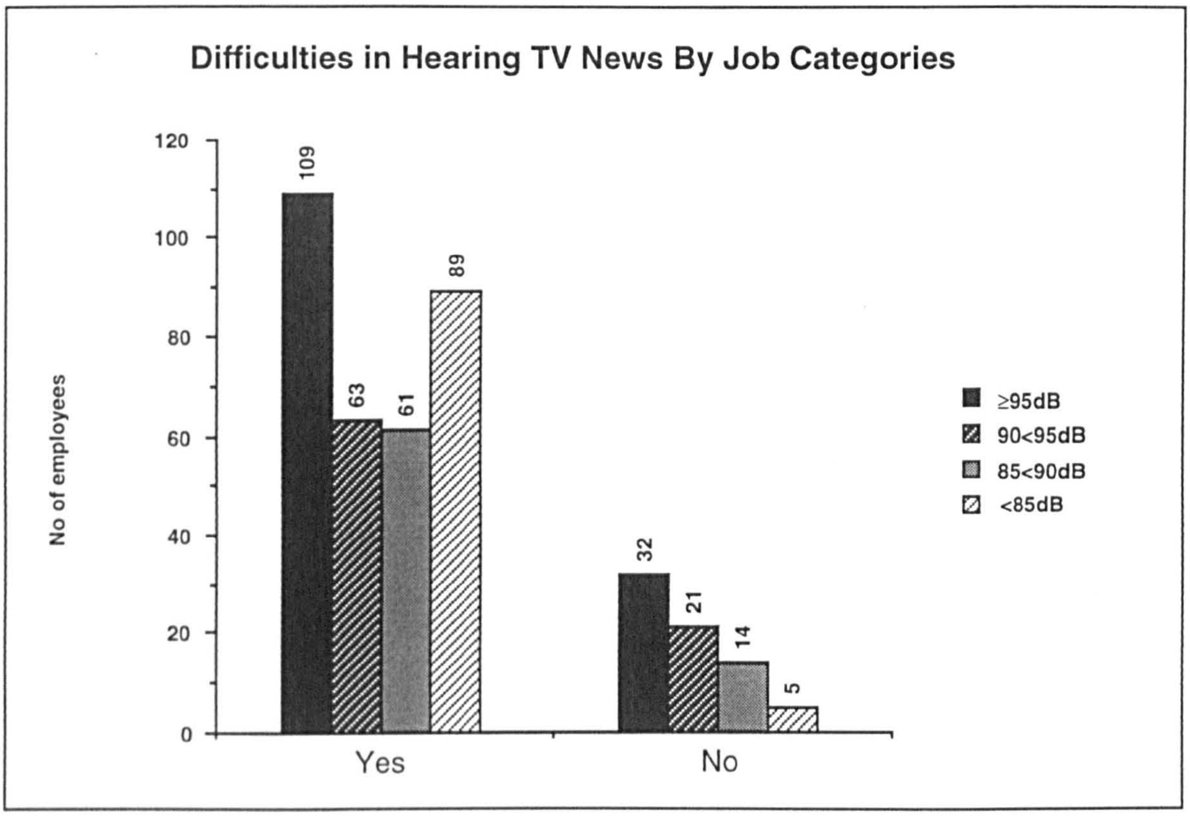
With regard to sex, there was no significant difference between male and female (p>.18). Out of the 263 male, 75 answered yes (28.5%) and of the 131 females, 29 answered yes (22.1%) (See Fig 7.3).

FIGURE 7.3



In *question 2* in *part 4*. A significant difference was shown by using Chi - square according to job categories (p<.002). Mainly because a few people reported difficulty hearing TV news when the volume is turned up only enough to suit other people; however, in job categories receiving less than 85dB, only 5 out of the 94 have difficulties of hearing but the other groups have more workers reporting difficulties of hearing eg 14 out 75 in the cat egories over 85dB & <90dB (See Fig 7.4)

FIGURE 7.4



Question 3 of *part 4* addressed the question of perceived hearing loss in different job categories. Ten workers out of 394 and 14 workers out of 394 reported significant hearing loss in the night and left ears respectively.

In job categories <85dB no more than 5 employees reported difficulties of hearing in either right or left ear. But in job categories >85dB 59 employees reported difficulties in hearing more in the left ear than the right.

(See Figure 7.5a and 7.5b)

FIGURE 7.5a

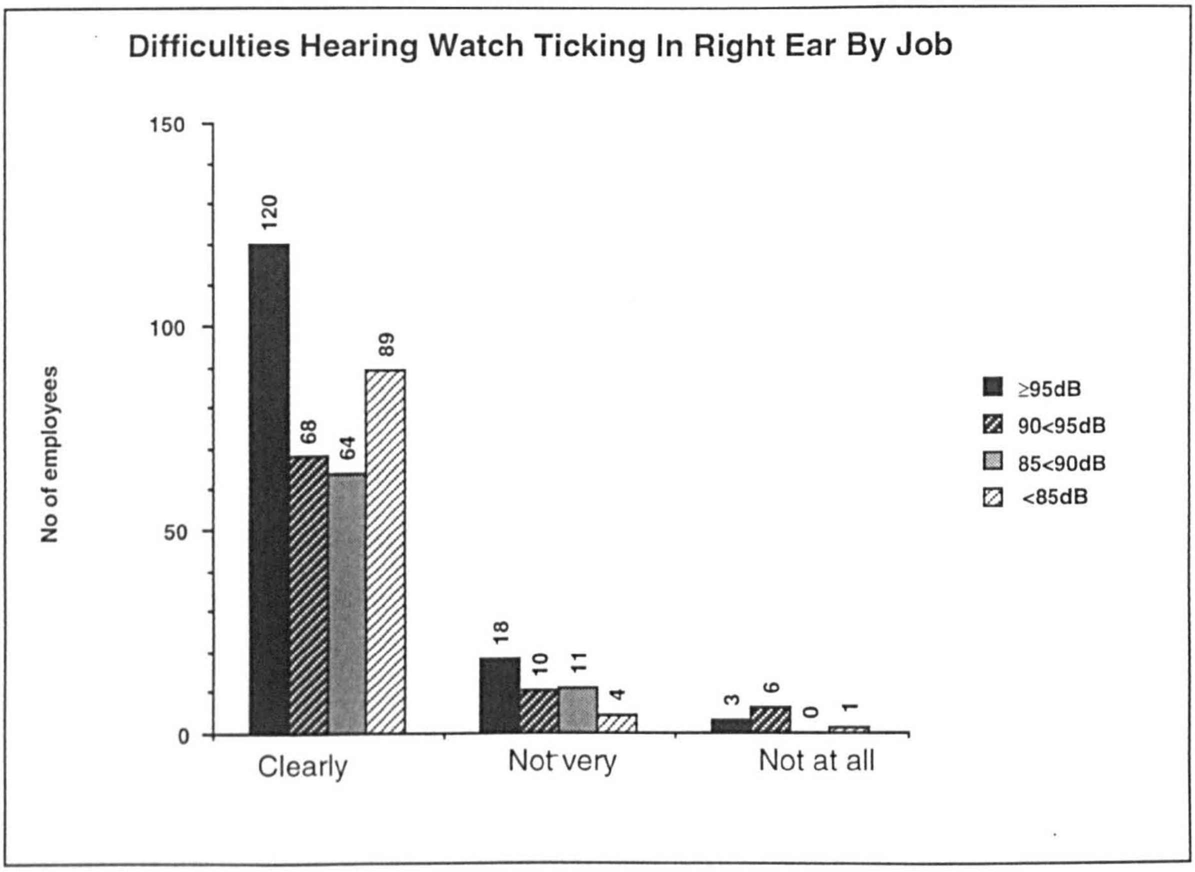
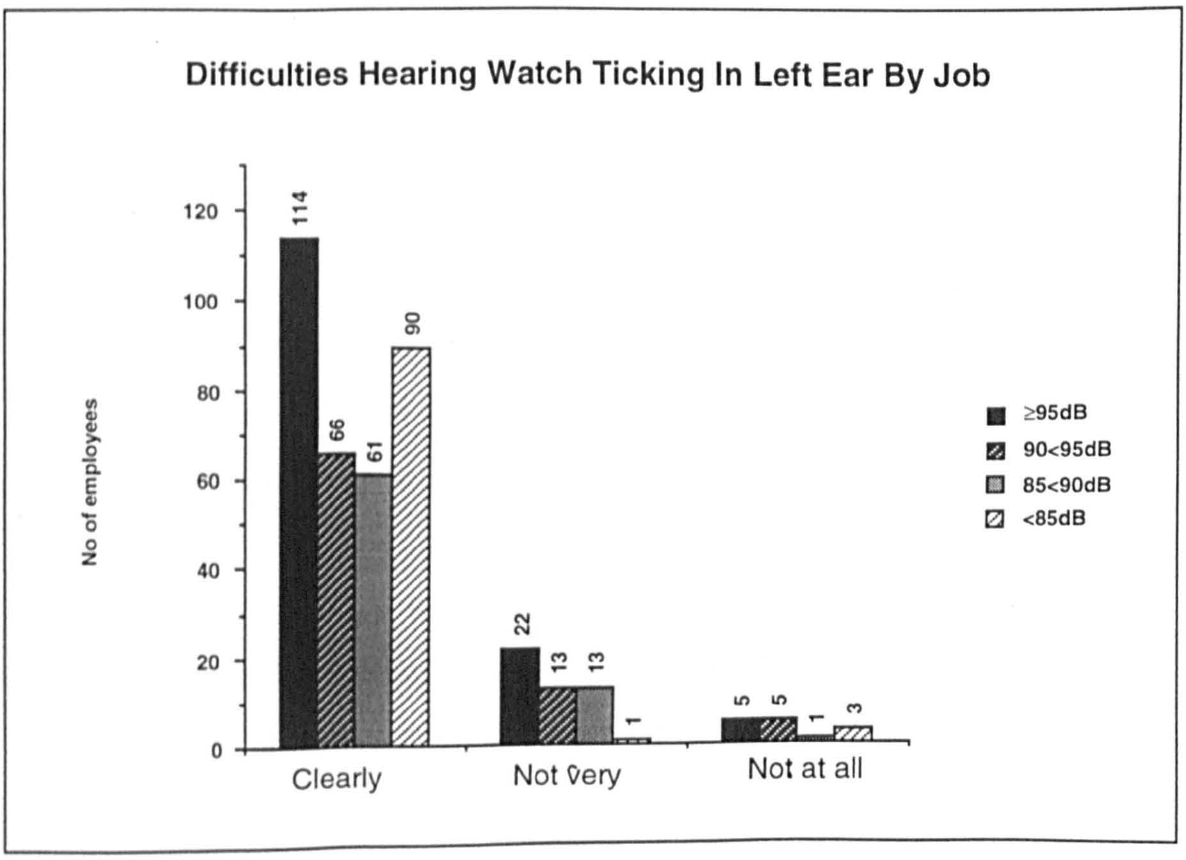


FIGURE 7.5b



7.3 Other Sources of Hearing Defects

The workers were asked to identify exposures to other noise sufficient to affect hearing.

Many types of entertainment, leisure and sporting activities can give rise to noise problems both from the point of view of hearing damage and environmental noise pollution. Obvious examples are pop concerts, discotheques, game and clay pigeon shooting, motor sports, watersports and the flying of model aircraft. Much work is being carried out in the preparation of codes of practice to produce guidelines for the control of noise from many of the above activities.

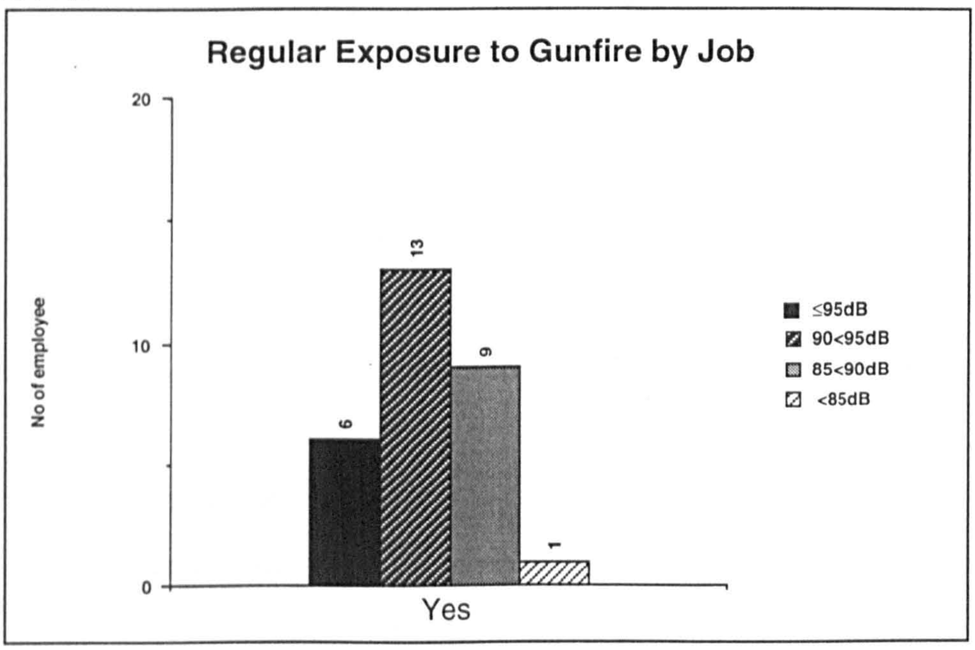
Many sporting activities threaten hearing as well as causing problems in terms of environmental noise. Davis et al have concluded that exposure to noise during leisure activities can, in extreme cases, be equivalent to an occupational exposure of 80dB (A) over a working lifetime. For those jobs with a high noise exposure, already subject to noise around the first action level or more, leisure noise can effectively double the risk of developing hearing loss (Adams & McManus, 1994)[46].

The shooting of guns at game or clay targets produces very high levels of noise in the immediate vicinity of the shooter's ear. A single shot gun blast, registering 140 decibels can permanently affect hearing. Any noise that forces one to shout to be heard poses a danger to auditory capability (Allen, 1990)[30].

In Part 5 Question 1a, employees were asked if they had been exposed to gunfire or explosions (fig 7.6a) and 96 of them had from replies to question 1b, was it regular exposure or not (fig 7.6b), it was clear that only a few of them (29 out of the whole group) were regularly exposed. Further investigation, of each one of the employees who responded to this part of the questionniare showed that none of them have difficulty in hearing.

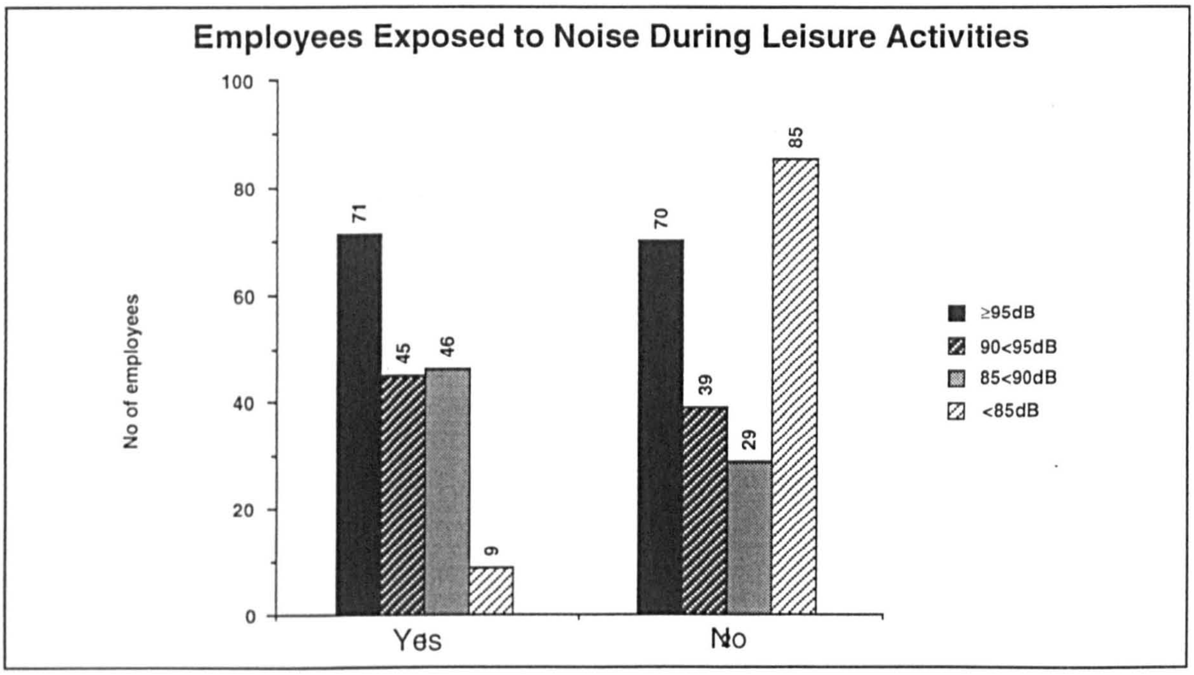
FIGURE 7.6

FIGURE 7.7



Part 5, Question 2 investigated other sources of noise associated with leisure eg. loud music, ear phones, night clubs, football matches etc A total of 171 employees had been involved in these activities but not on a regular basis. Most of them are in categories >85dB, and only 9 were in categories <85dB.(See Figure 7.7)

FIGURE 7.7



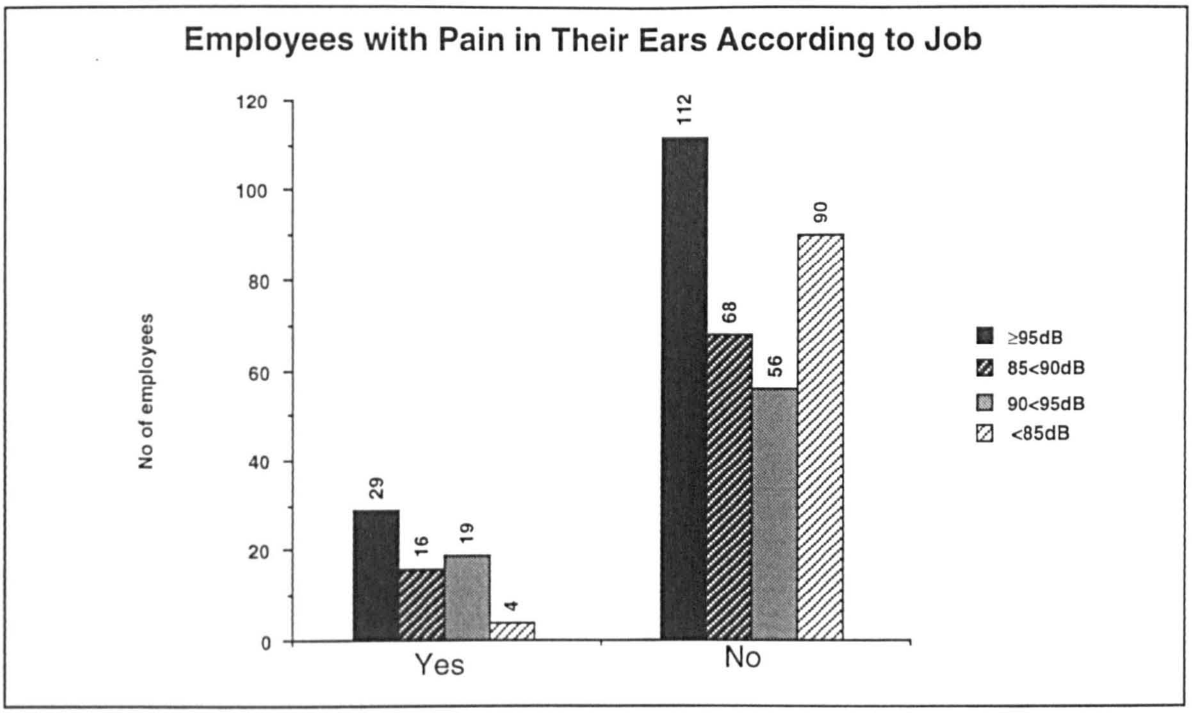
7.4 Ear Problems

In *part 6*, an investigation was made into various ear problems. By using chi-square tests the result shows no significant differences according to sex or age, therefore this will not be discussed further.

7.4.1 Pain in the ear

Statistically significant differences were found between job categories ($p<0.001$) because in group <85dB only 4 employees had pain in the ear. On the other hand groups >85dB had shown a higher number of 64 workers had reported pain in their ears. (See Figure 7.8)

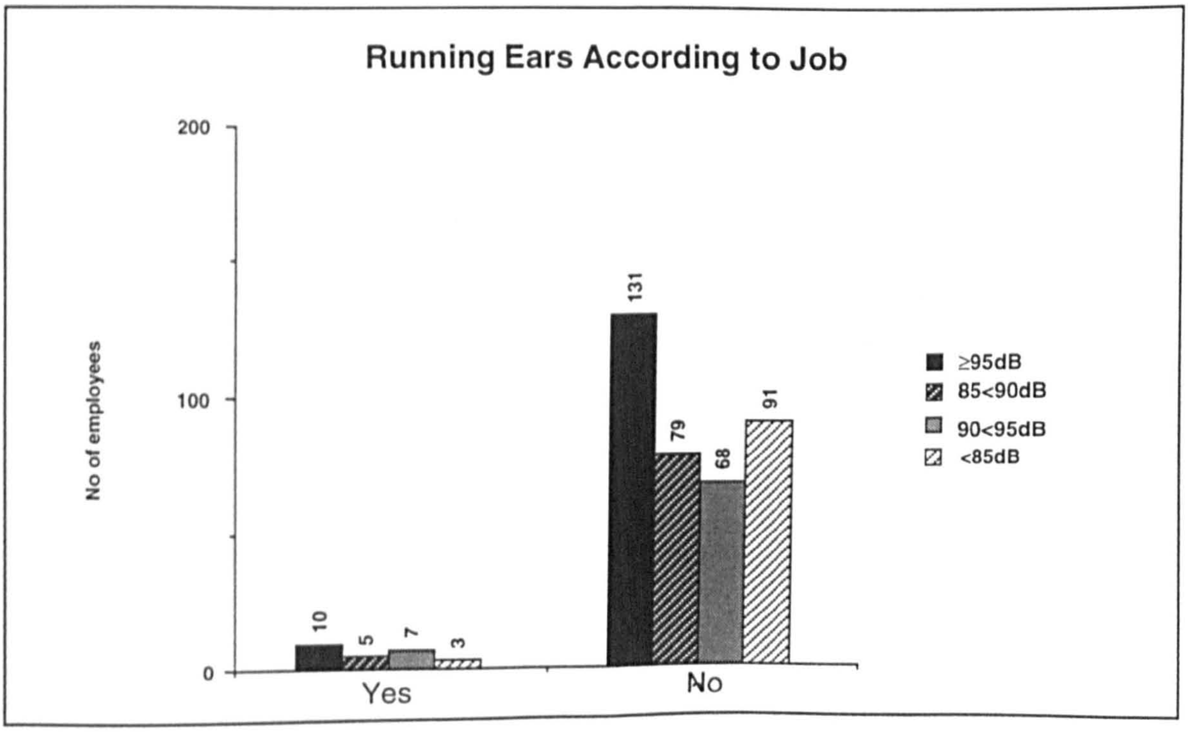
FIGURE 7.8



7.4.2 **Running Ears**

Very few workers reported running ears and there was no deomostable association with job category. (See Fig 7.9).

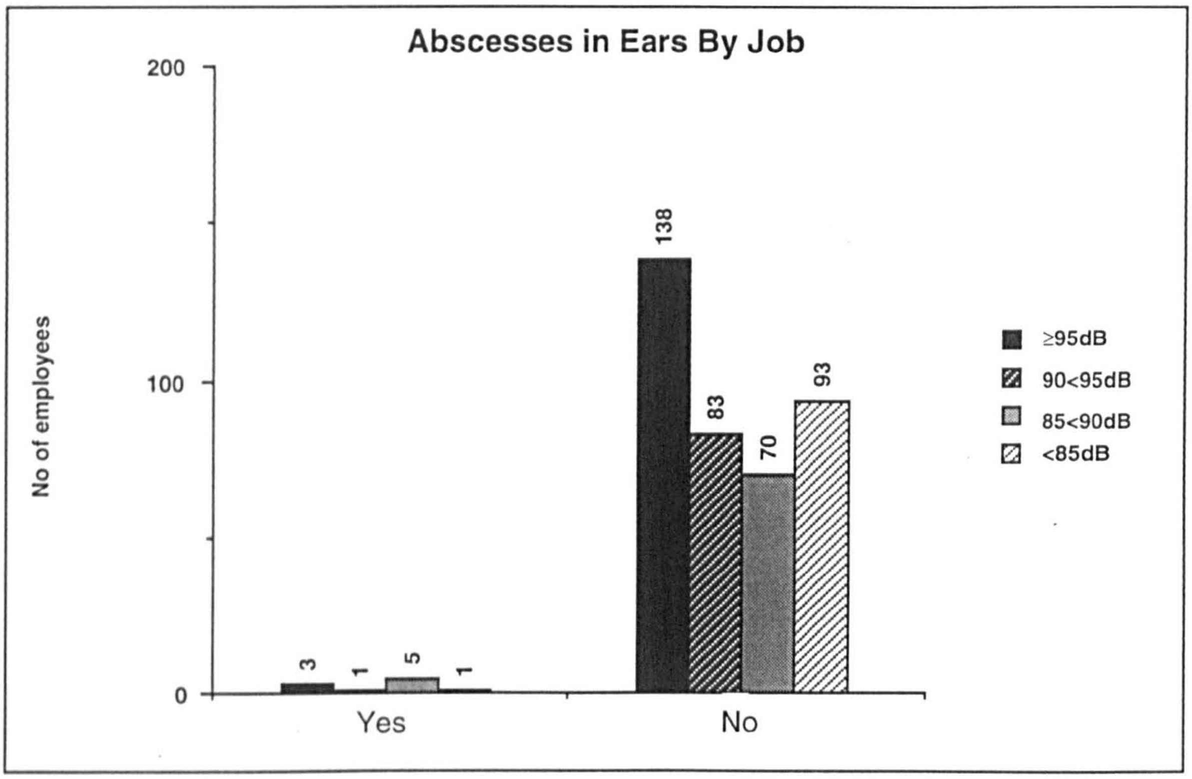
FIGURE 7.9



7.4.3 Abcess in ears

Very few employees reported abcesses in the ear and there was no evident association with job category. (See Fig 7.10)

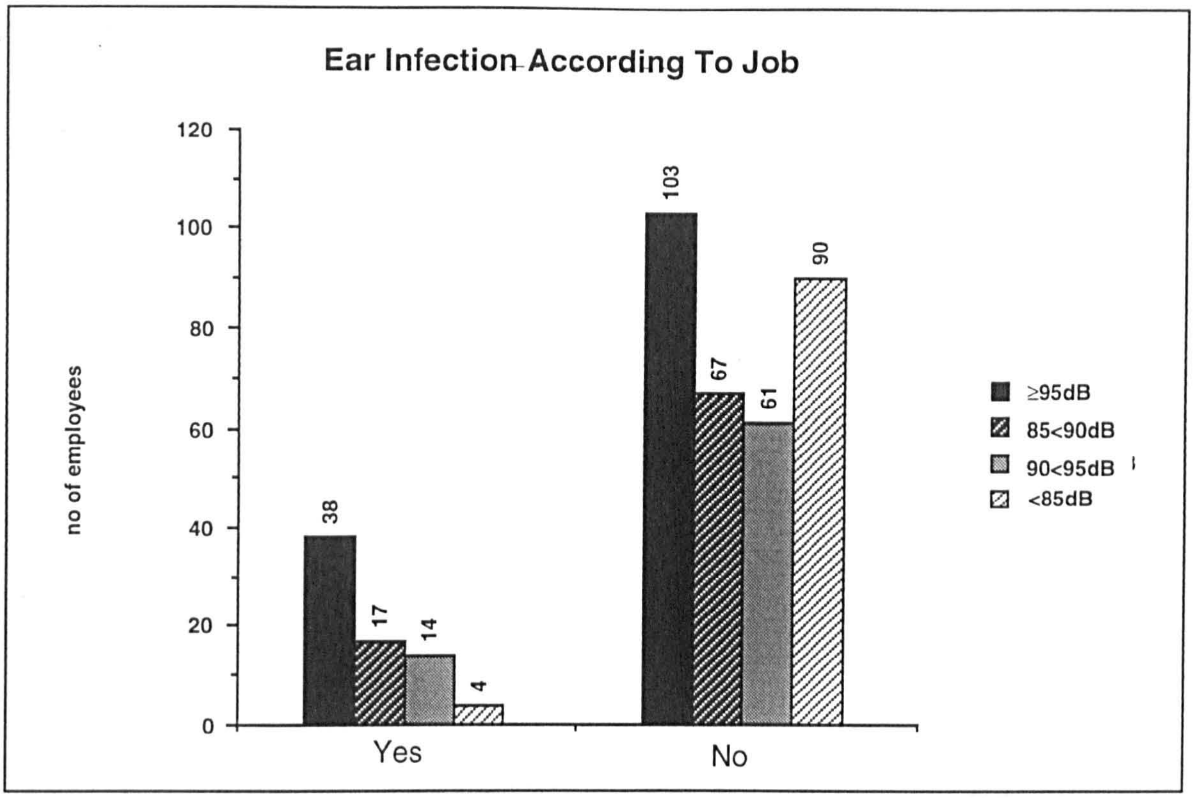
FIGURE 7.10



7.4.4 Ear infection

Ear infections were reported in all job categories with the lowest rates in job category (85dB). The occurence of ear infection was significantly higher in all other job categories. (See Figure 7.11)

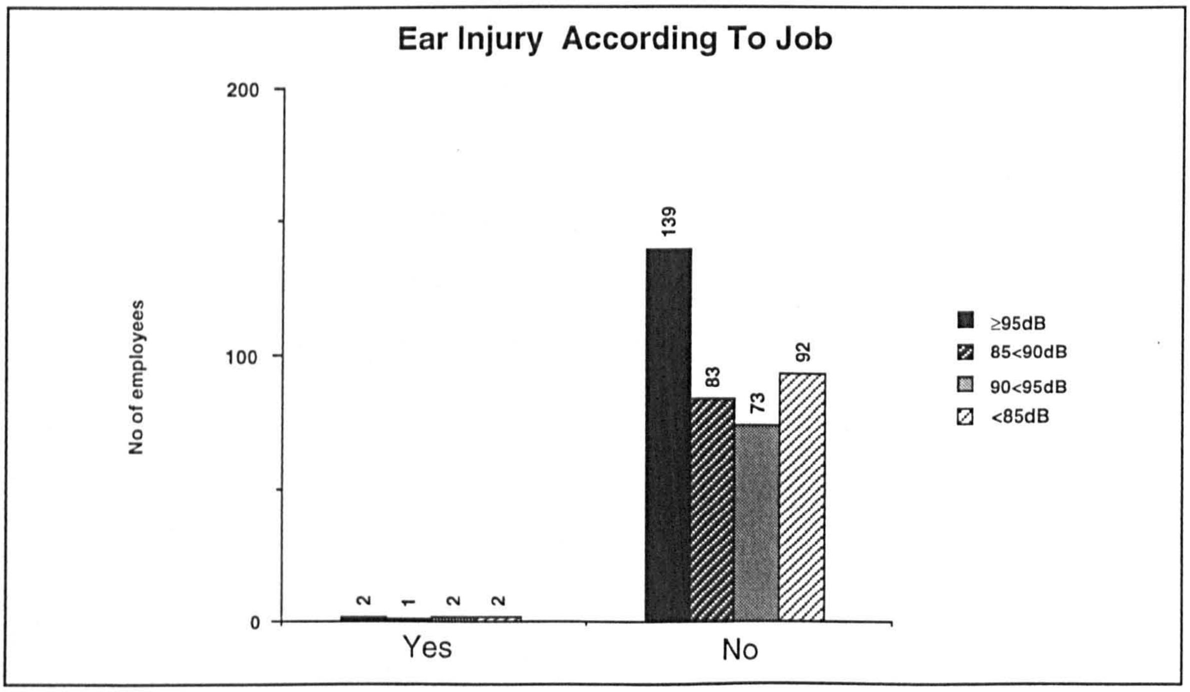
FIGURE 7.11



7.4.5 Ear injury

No significant differences were shown between job categories (p>.87). Only 7 employees out of 394 reported ear injury and that number was equally distributed between all categories. Fig 7.12 shows these re sults.

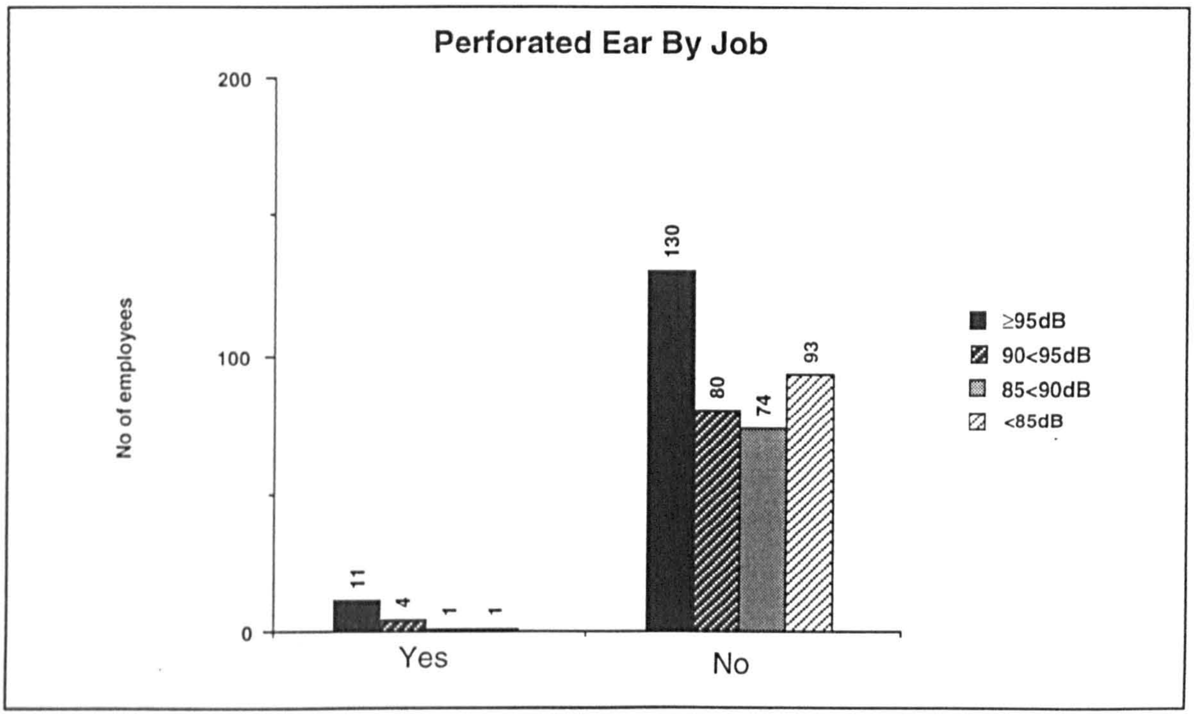
FIGURE 7.12



7.4.6 Perforated eardrum

Though only 17 cases of perforated ear drums were reported in 394 responses (fig 7.13) almost all cases occurred in those exposed to >90dB

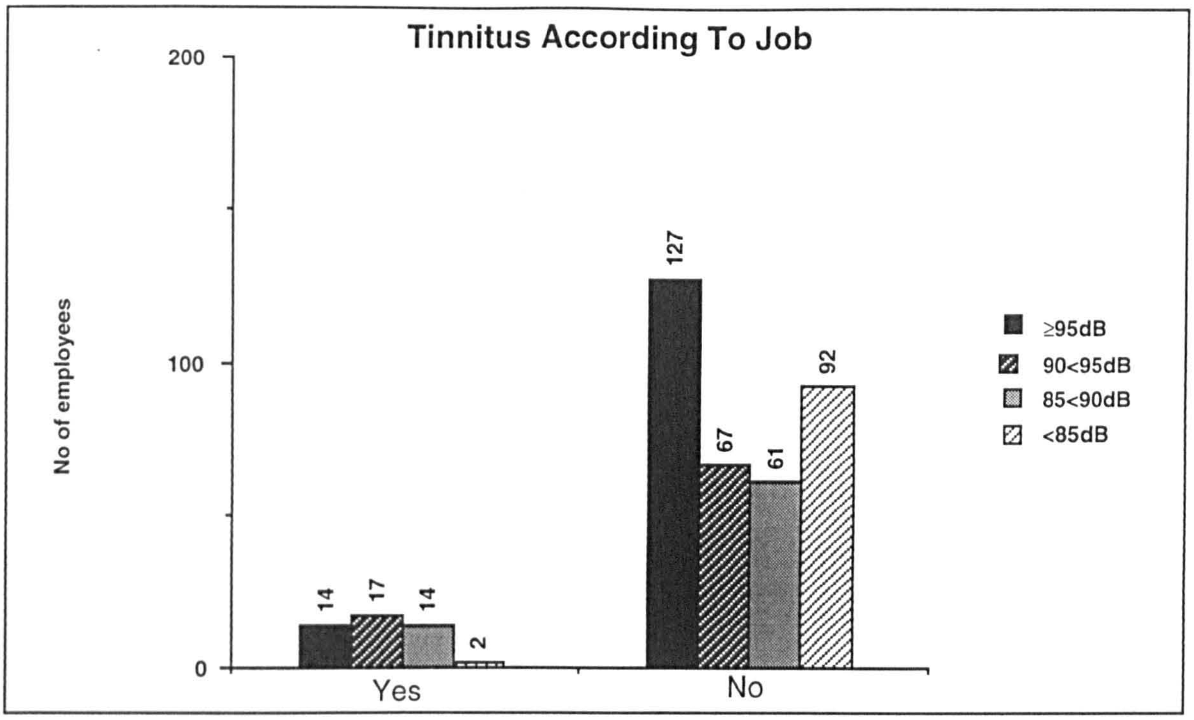
FIGURE 7.13



7.4.7 Noises (Tinnitus) in the ears

47 employees reported tinnitus problems in all job categories. Even so, the result was significant (p<.00) because only 2 employees out of the 94 reported tinnitus in job categories <85dB (Fig 8.14). On the other hand, the other job categories with higher than 85dB reported more cases eg. 40 out of 75 in category 85<90dB.

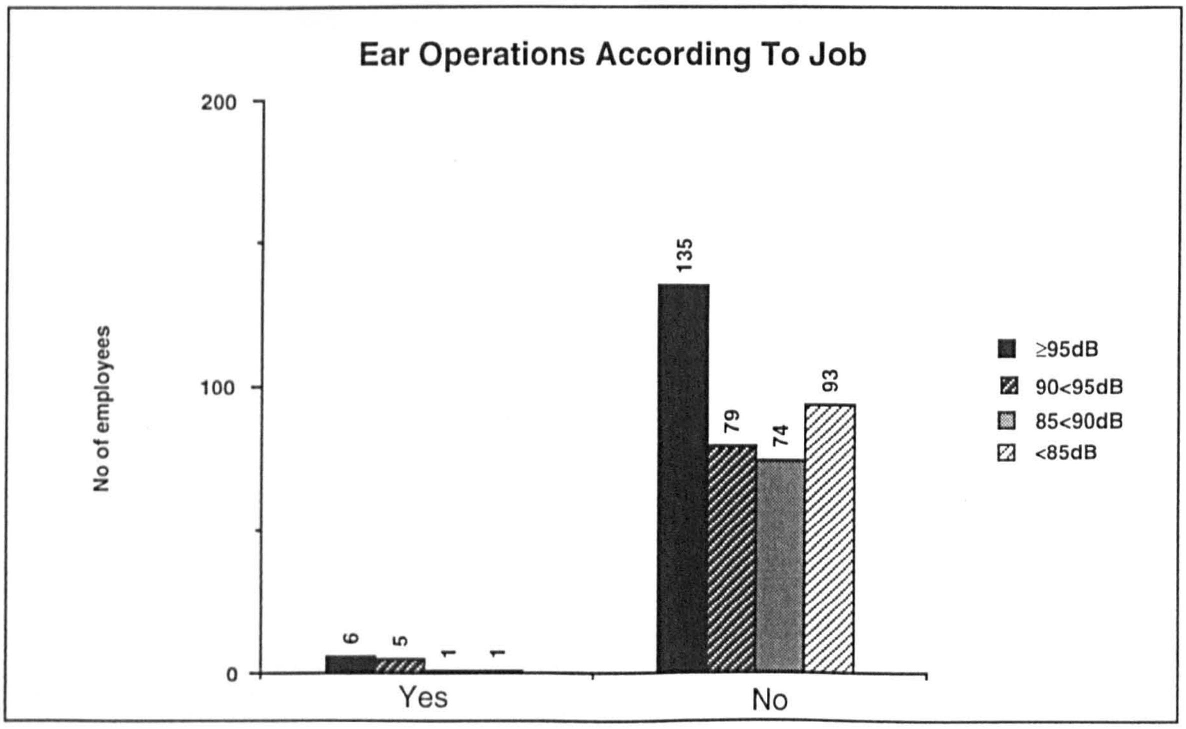
FIGURE 7.14



7.4.8 **Operation on the ears**

Only 13 people reported ear operations and these were equally distrib uted in all job categories. See (Fig 7.15).

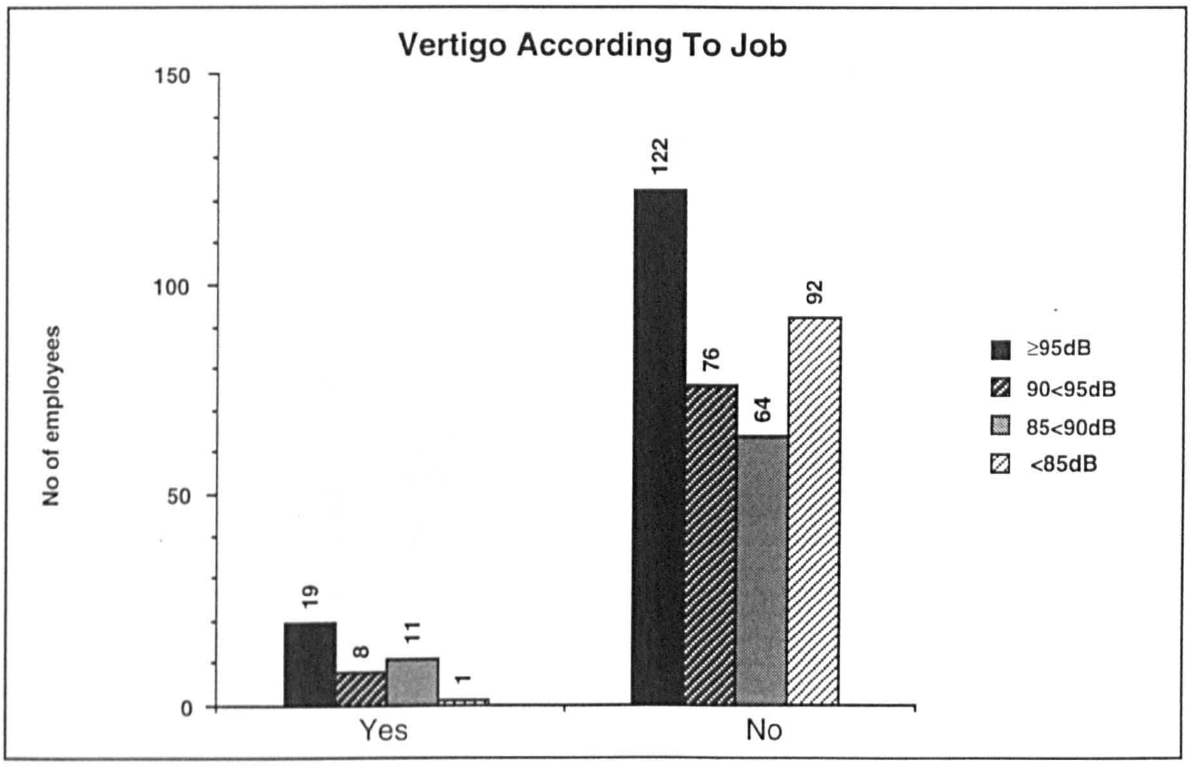
FIGURE 7.15



7.4.9 Vertigo (suffer from dizziness)

The result was significant (p<.02) Because out of 40 cases only 1 appeared in job categories receiving <85dB. The rest were equally distributed in the remaining job categories at almost same percentage (fig 7.16).

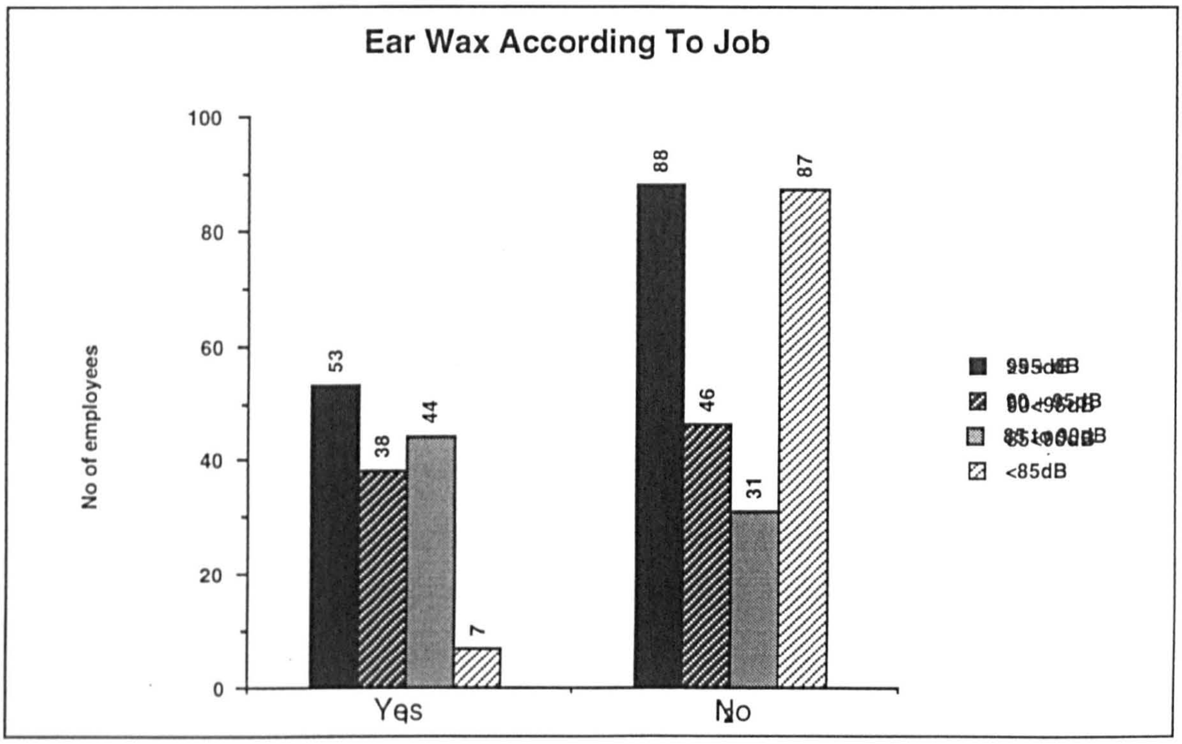
FIGURE 7.16



7.4.10 Wax in the ears

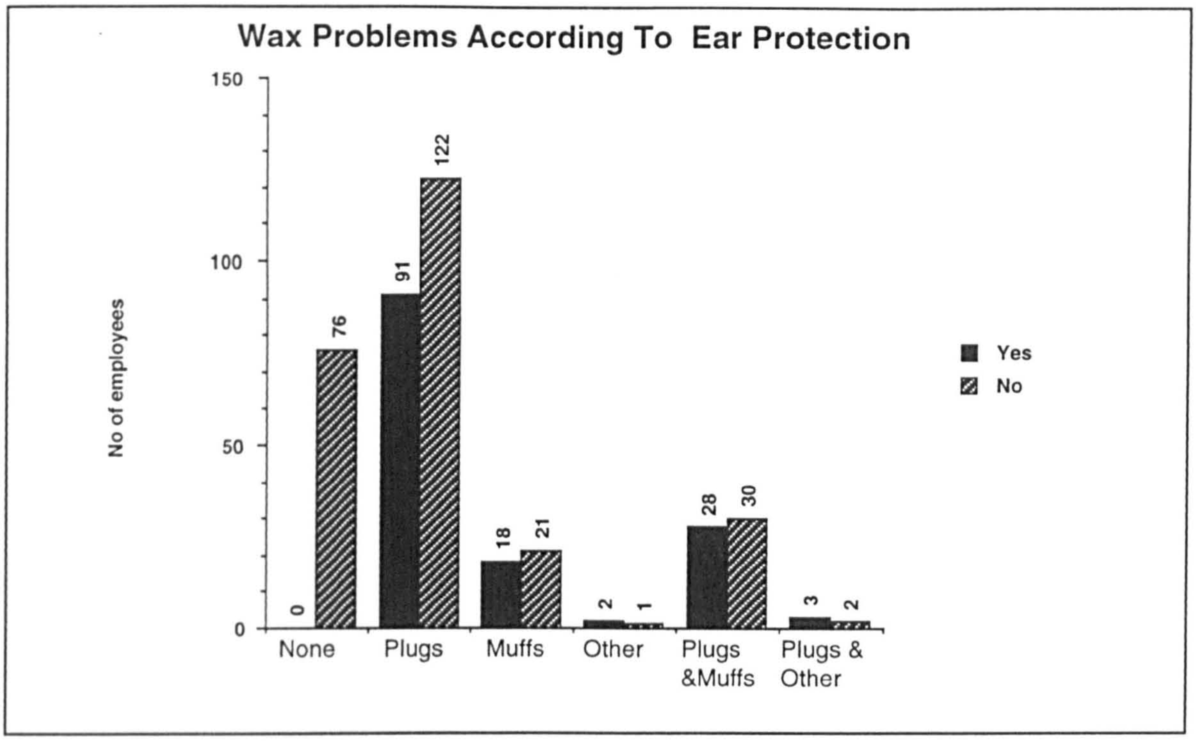
The result was significant (p<.00). The group 85<90dB reported a higher number of employees complaining of wax in the ears, a percentage of 59% compared to 7.4% in job categories <85dB (Fig 7.17a).

FIGURE 7.17a



A significant proportion of all employees - 36% reported wax in the ear. This was more common in these job categories exposed to higher noise levels where wearing some protective gear was necessary. The highest number of earaches were absorved in workers using ear plugs as opposed to muffs .(See Figure 7.17b)

FIGURE 7.17b



7.5 General Health Problems

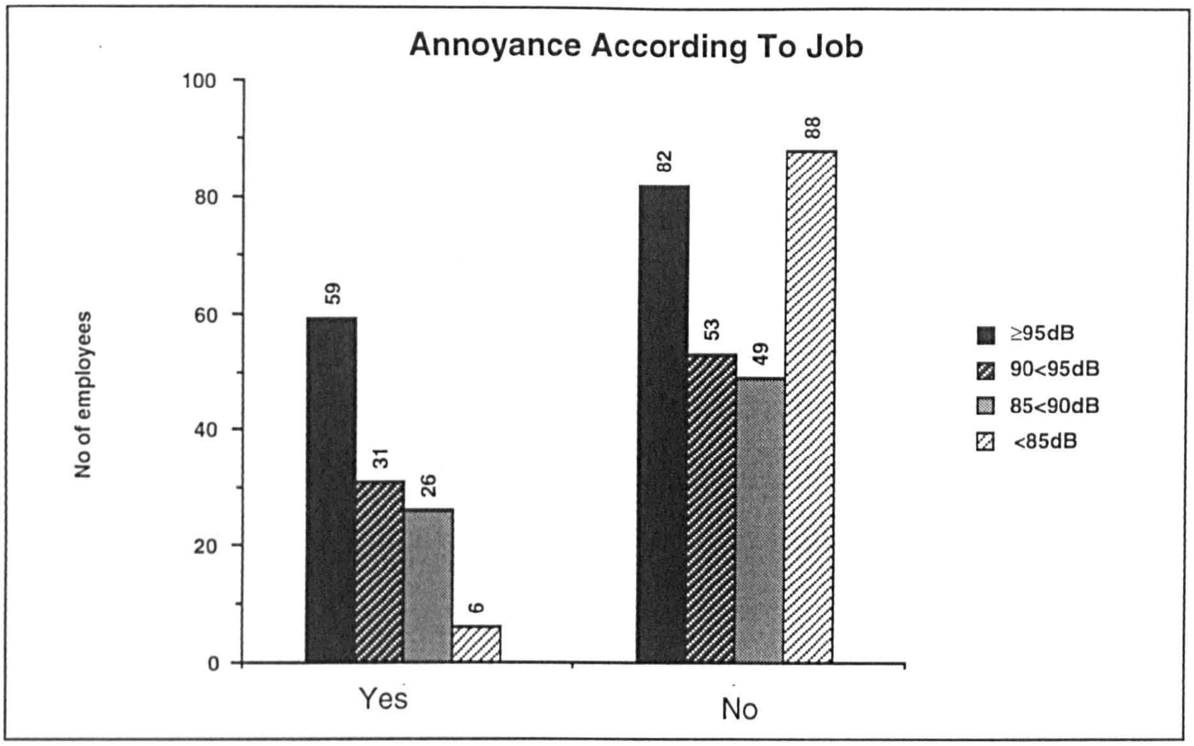
There are some health problems maybe asociated with industrial noise, eg, high blood pressure, sleep disturbance, annoyance, smoking, which will be explored in this chapter.

7.5.1 Annoyance (headache and mood changes)

The World Health Organisation (WHO) definition of annoyance is "a feeling of displeasure evoked by noise". Although it is compratively easy to define annoyance due to noise it is an extremely difficult response to quantify mainly because of the wide variation in response from a number of subjects exposed to the same noise source (Adams & McManus, 1994).[46]

There were no differences between the sexes or age groups. More people reported having experienced annoyance in categories over 85dB ranging from 6.4% in category <85dB up to 40% in both categories 90<95dB and ≥95dB. (Fig 7.18) shows those differences.

FIGURE 7.18



7.5.2 **Sleep Disturbance Effects**

Exposure to noise can induce disturbances of sleep in terms of difficulty in falling asleep, alterations in sleep pattern or depth, and frequent awakenings. These effects are referred to as primary sleep disturbance effects (Bergluand, Lindall, Nordin, 1990).[76]

Disturbances in sleep is one of the most common forms of annoyance due to noise and of all the forms of annoyance is probably the least tolerated. Other problems which were encountered in research into noise and sleep disturbance are:

1. Sleep disturbance is largely influenced by the age of the subjects, eg, sensitivity to sleep disturbance is lower in children than in adults and the elderly tend to be disturbed most.

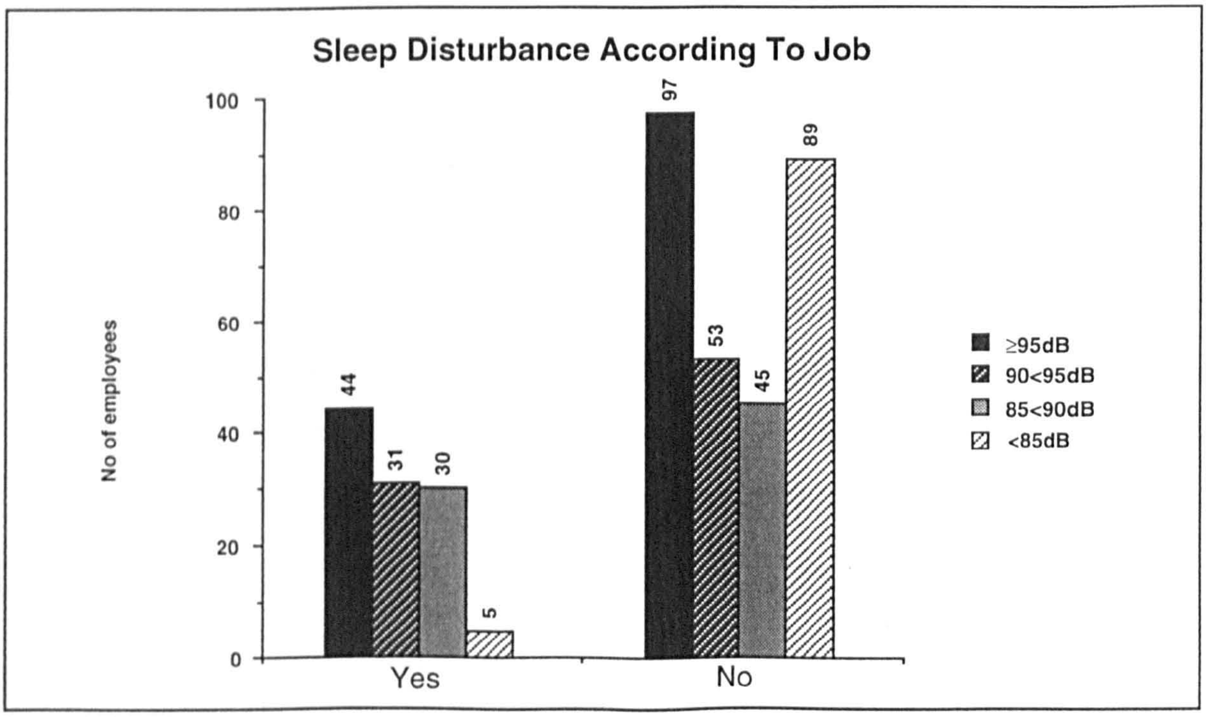
2. Many people have sleeping difficulties unrelated to noise. Langdon and Buller found in a survey of sleep disturbance due to road traffic noise in Greater London that about 20% of people suffered from sleep disturbance for reasons other than noise. The main reasons were related to health, anxiety, discomfort and insomnia.

3. Physiological habituation, ie, people become adapted to sleeping with a certain degree or type of noise. It is generally accepted, however, that little or no adaptation occurs for internal noise levels above 60dB(A) (Adams & McManus, 1994,).[46]

Differences were observed in the study between job groups but not between the sexes or age groups. It is clear that people who received ≥85dB complained more than those in categories <85dB See (Fig 7.19) presents the numbers of employees who had diffi culty of sleeping.

Like other forms of noise annoyance, sleep disturbance is influenced largely by the nature of the noise source as well as the noise level.

FIGURE 7.19



7.5.3 Blood Pressure and Noise

Apart from the auditory effects of noise on health there is litle convincing evidence that noise causes physical illness. Evidence of the effect of noise on the cardiovascular system is equivocal.: the balance of opinion is that of noise raises blood pressure (Stansfield, 1992).[7]

Johnsson and Hansson, (1977)[77] also made a study, but their workers were significantly older than those studied by Cohen et al. It may be possible that noise augments the usual rise in blood pressure associated with age. Only 1200 workers met screening requirements to be included in the hearing loss group. This may mean Cohen et al were studying a group showing aunique re physiological adaptation to stress. Measurements of blood pressure are influenced by a host of factors. Levels reported by Cohen et al were low compared to normal. This may reflect the method of taking the blood pressure (with the person lying down) or even the time of year. This study was conducted during the hot, summer months when vasodilation and salt/fluid loss through perspiring could lower blood pressure.

Kent, Gierke and Tolan (1986)[78] looked at the relationship between prolonged exposure to noise and chronic cardiovascular disease. The degree of high tone hearing loss diagnosed, along with a high probability of being noise-induced was used as an indicator of the extent of relative noise exposure. This retrospective study looked at the medical records of 2,250 Air Force crew members (pilots of navigators) who had been referred to the USAF School of Aerospace Medicine between 1957-1980 for evaluation of borderline conditions which disqualified the aircrew members from flying duty. They had to meet stringent medical criteria prior to selection for flight duty. A blood pres sure greater than 140/90 would mean a course of treatment. Therefore the sample in this study could be considered very fit. The age ranges were 19-57 years. A polynomial regression of blood pressure data, using age as the independent variable, was determined for the maximum (upper third) and minimum (lower third) hearing loss groups. The quadratic regression provided the best fit for both hearing loss groups. There was little difference in the regression curves of those with maximum hearing loss and those with minimum loss.

Delin (1984,1988)[79, 80] also found no relationship between noise-induced hearing loss and hypertension. The first study (112 men from the engine rooms of ferries) were studied over a period of 8 years. Noise levels in the engine rooms were 100-115dB and 75-80dB in control rooms. Hearing and blood pressure were tested every second year. No significant difference was found between those with impaired hear ing and those with normal hearing. Similarly, exposure to noise did not result in a greater frequency of hypertension. An interesting finding in this study was that those exposed to noise for a long time tolerated noisy surroundings surprisingly well. It could be that a degree of stress is more important in producing cardiovascular problems than is the actual noise level, which could explain why some studies have positive results and others negative.

There is also some suggestion that noise at work may be associated with abnormalities of reproductive function and birth defects, but at the moment there is little evidence on this subject, although it should be looked at in depth in further studies.

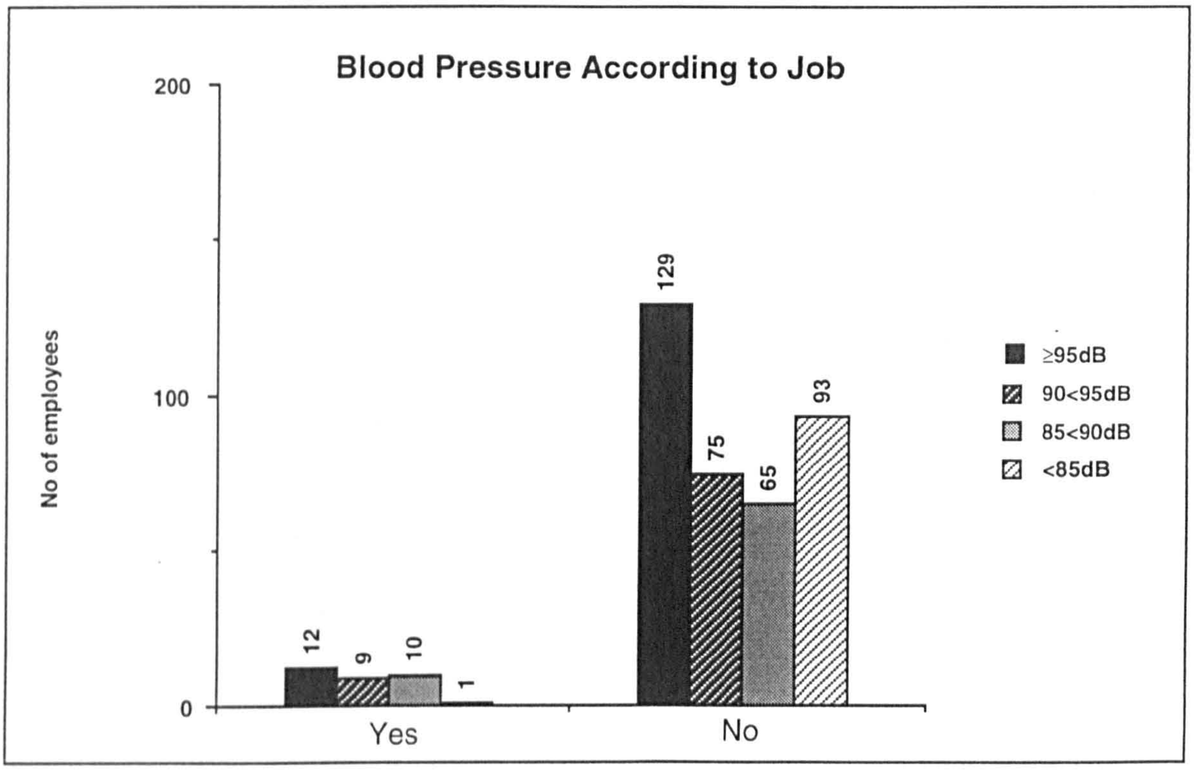
Health problems which cannot be accounted for by known risk factors, eg, heart disease account for a huge percentage of all deaths, therefore noise reduction may reduce the risk for many people, even if association between noise and cardiovascular dysfunction is only slight. Further research is required in this area. This could greatly enhance our knowledge of mechanisms linking stress to ill-health, and help us explain the problems which, at this time, have no known cause.

The main problem is that we do not know how much noise reduction is required to remove non-auditory effects at work. While results from previous studies provide a prima facie case for expecting non-auditory effects of noise we do not know whether they adequately reflect the situation in the workplace. In order to obtain information on the impact of noise at work it is necessary to carry out a longitudinal prospective study which considers many types of noise and different jobs.

There is some evidence from laboratory studies that noise influences blood pressure. These effects have been shown in both human beings and animals. Typically habituation is noted following these short-term exposure periods. Occupational studies find mixed evidence with most studies indicating higher levels of blood pressure among workers in noisier areas of industrial plants or when comparing workers across occupations differing in noise levels (Bergluand, 1990)[76].

At Don and Low studies show no differences between males and females with regard to blood pressure. A total of 32 cases reported blood pressure. Eleven of them are heredity cases. Significant differences between groups ($p<0.02$) indicate that noise may affect blood pressure levels amongst employees in job categories >85dB, as 21 employees, with no hereditary history of high blood pressure were in this category. Categories <85dB reported one case (hereditary).
(See Figure 7.20)

FIGURE 7.20



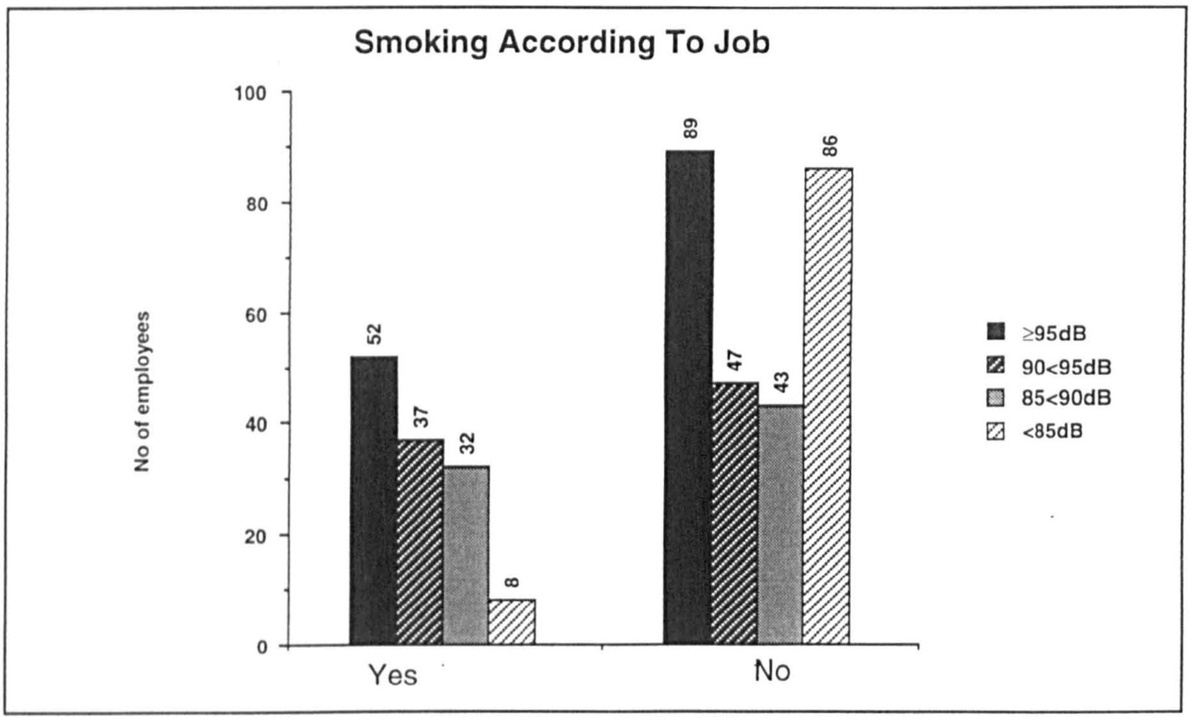
7.5.4 Smoking

As is well known smoking is a main cause of cardivascular diseases, lung cancer and other health problems. Industrial noise may accerbate the situtaion by increasing the number of smokers among employees.

Statistically significant differences($p<0.01$) between job categories would indicate noise may intefere with increasing number of smokers amongst job categories exposed to high level of noise.

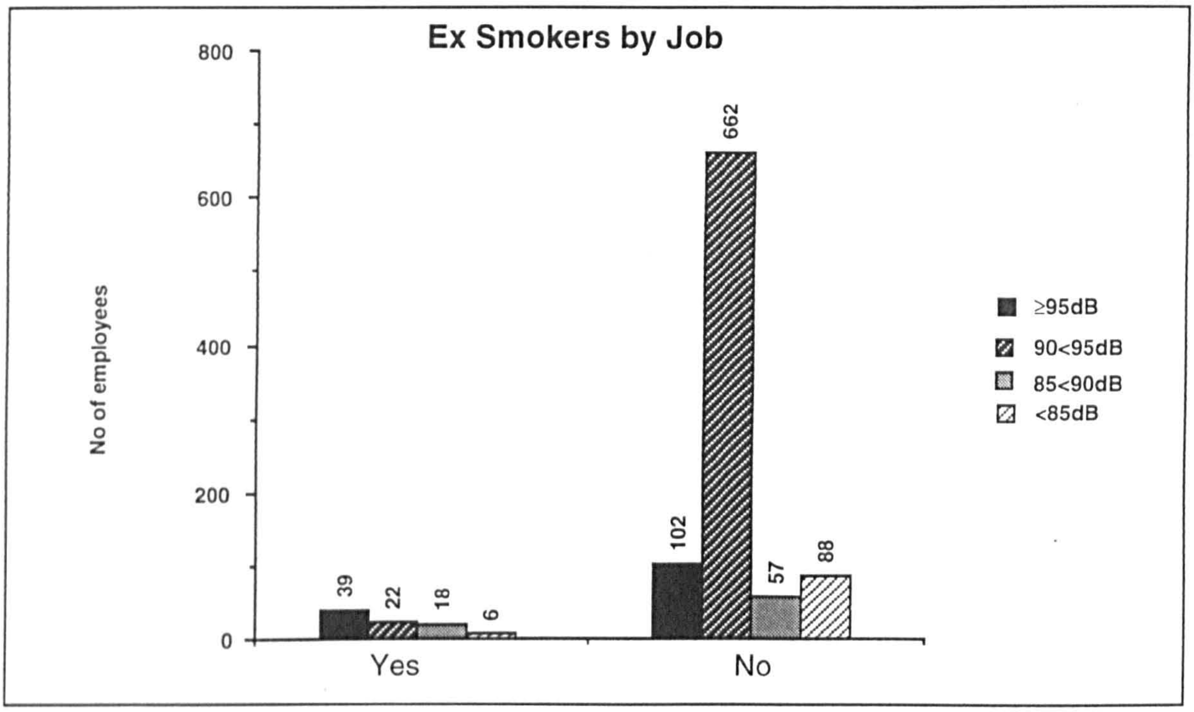
The number of smokers are 129 out of the 394 who responded which gives a percentage of 32.7%. Also, the proportion of smokers is higher in groups exposed to >85dB ranging from 36.9% to 44.1% and only 9% in job categories <85dB. (See Fiure 7.21a)

FIGURE 7.21a



The company has run a campaign to control this habit and they have encouraged 85 employees to stop smoking. It was significant (p<.00) that most smokers were in job categories ≥95dB. See Fig (7.21b)

FIGURE 7.21b



7.6 Industrial Accident and Noise

As discussed in previous chapters industrial accidents are more frequent in noisy environments. The results at Don and Low studies were no different. Empolyees working in a quiet environment reported fewer accidents than those working in noisier environments. The more they are exposed to a higher noise level the more chance the employees have of having an acci dent: eg mainly minor cuts from scissors or metals, bumping into table legs etc.

The number of accidents entered by the employees on the questionnaire is 1060, a ratio of more than 3 accidents to 1 employee. Comparing the actual figures given by the company only 186 accidents were reported in all sites of Don & Low See (Table 7.1), which means that the employees are not re porting accidents to the company. Plants with a noisy environment had more accidents than the others.

TABLE 7.1: The manual reported accidents at Don & Low

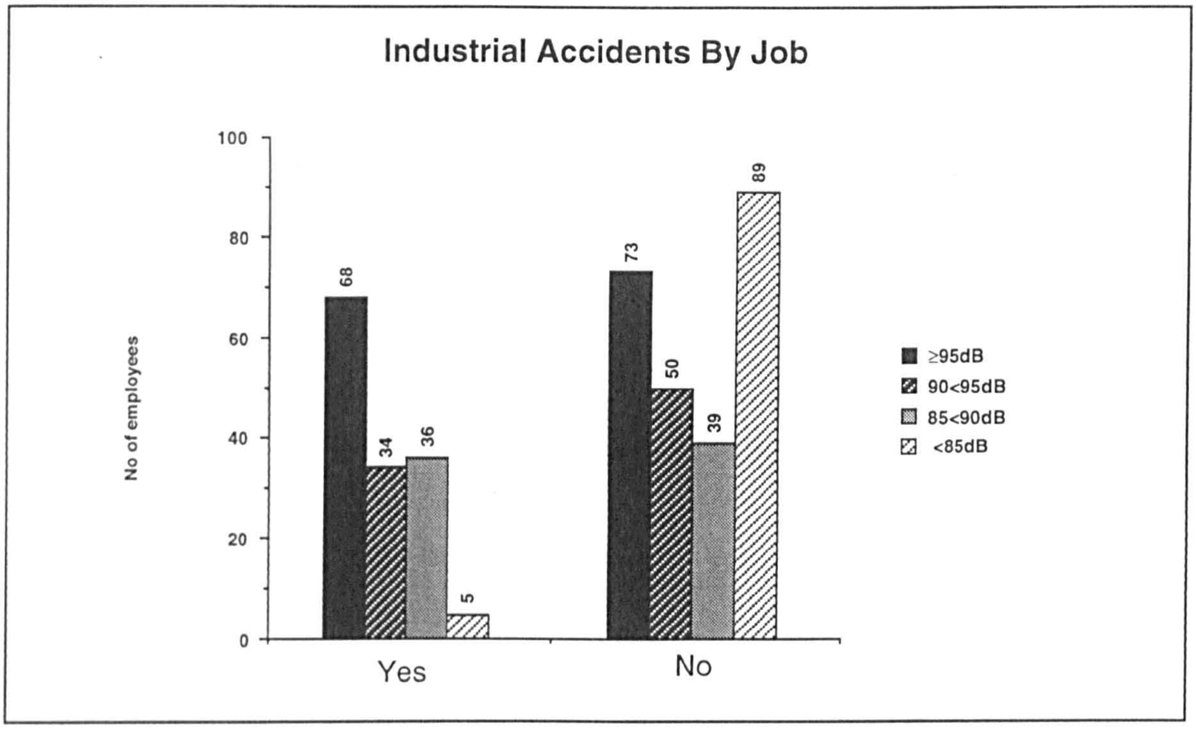
Wallace Works	St James	Canmore	Nonwoven	Newford Park	Broadcro	Head Office
44	34	44	9	37	1	11

On the other hand, the 1060 are not the total accidents because only half of the total number of employees responded to the questionnaire.

Noisy environments had a profound influence on accident rates. Employees in quiet environments reported less accidents than those in a noisy environ ment. *Fig 7.22 represents the distribution of accidents by job. The data suggests that almost all employees in job categories >85dB had an accident.

* The difference was statistically significant.

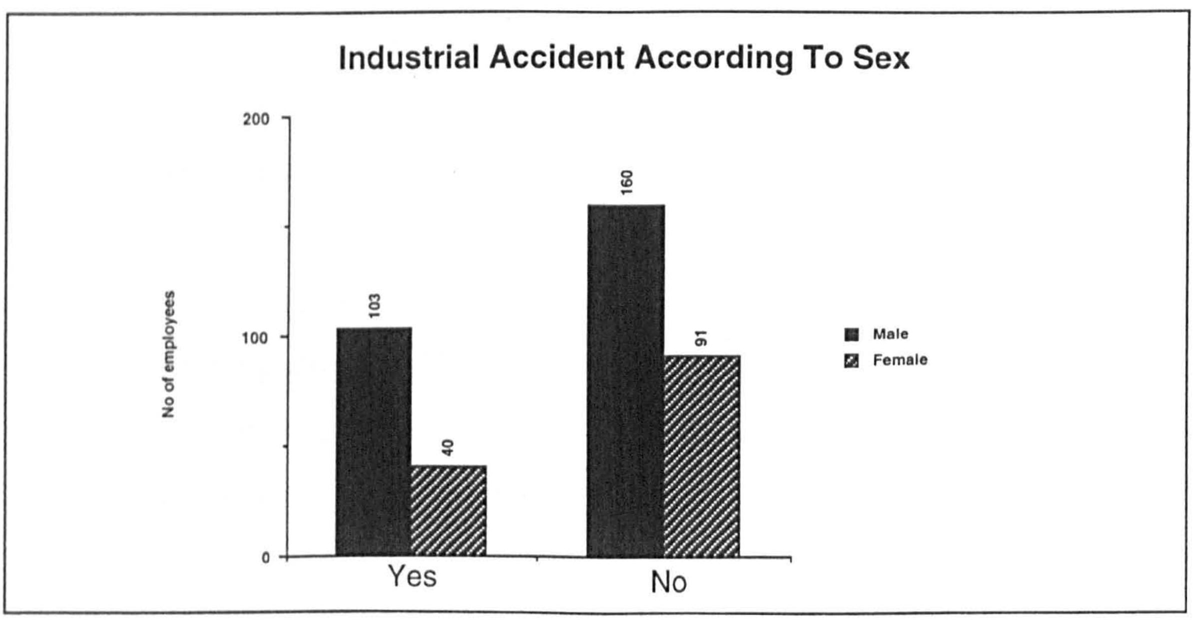
FIGURE 7.25



7.6.1 **Industrial Accident by Sex**

There was no significant difference in accident rates between men and women. Out of 263 male employees, 103 reported industrial accidents; on the other hand, out of 131 female employees, 40 reported industrial accidents , see Figure 7.23.

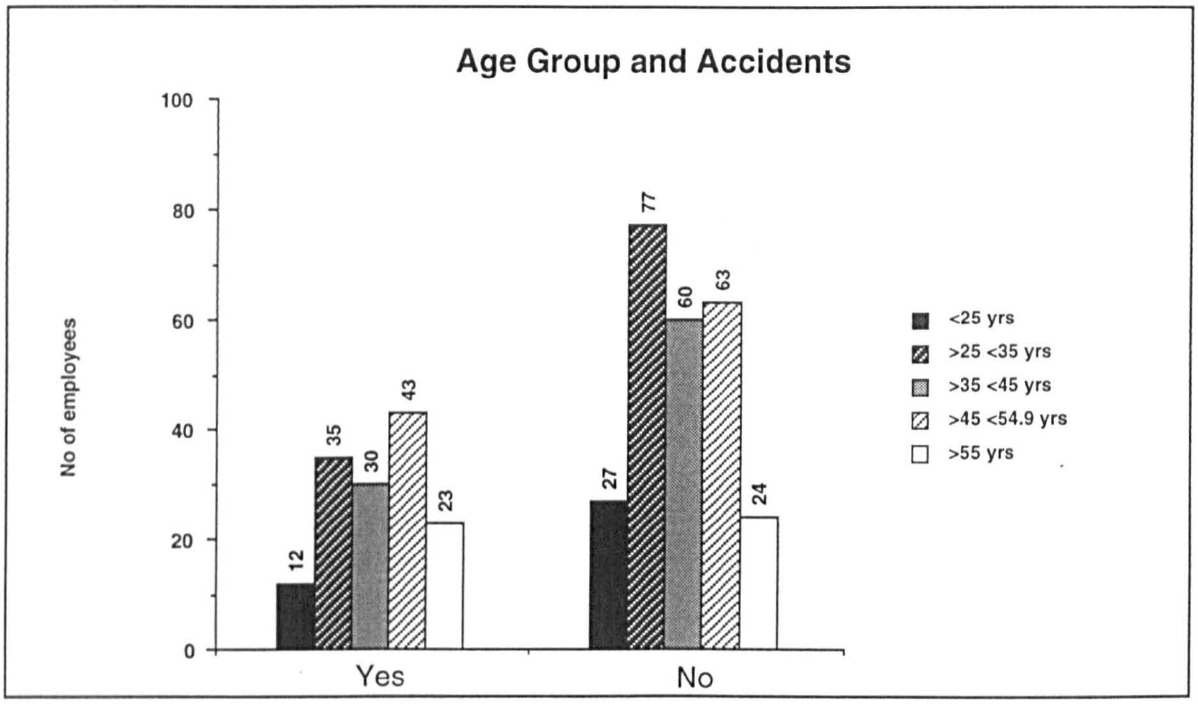
FIGURE 7.23



7.6.2 ***Age and Accidents***

A total of 133 employees reported industrial accident. Age does not appear to influence accident rates. Fig 7.24 illustrates the frequency of industrial accidents by age groups.

FIGURE 7.24



From interviewing the employees I felt that their response to this specific question ,(How many industrial accidents have you had?), gave unreliable results because their name appeared on the questionnaire. Therefore, I decided to introduce another questionnaire which would be anonymous when interviewing the employees, to ensure their trust and so that they knew that their response would be dealt with confidentially (see Appendix 3). This time only 217 employees responded. However, the results in Table 7.2 show that there is a statistically significant differ ence in the frequency of accidents and in different job categories. More accidents are reported in all noisy environments ≥85dB, specifically in job category ≥95dB where 323 industrial accidents were reported, whereas, in job category <85dB only 3 accidents were reported.

TABLE 7.2: Number of Accidents in All Job Categories

	Job Categories				
	≥95dB	90<95dB	85<90dB	<85dB	Total
N°. of accidents	323	172	71	3	569

They are not necessarily accidents by each worker. It may be that some of the employees have had more than one accident.

All accidents either reported or unreported to the management are presented in the table (7.3) according to their job categories. Employees working in a noisy environment reported that they have more acci dents than those who work in a quiet environment. The difference was statistically significant ($p<.001$).

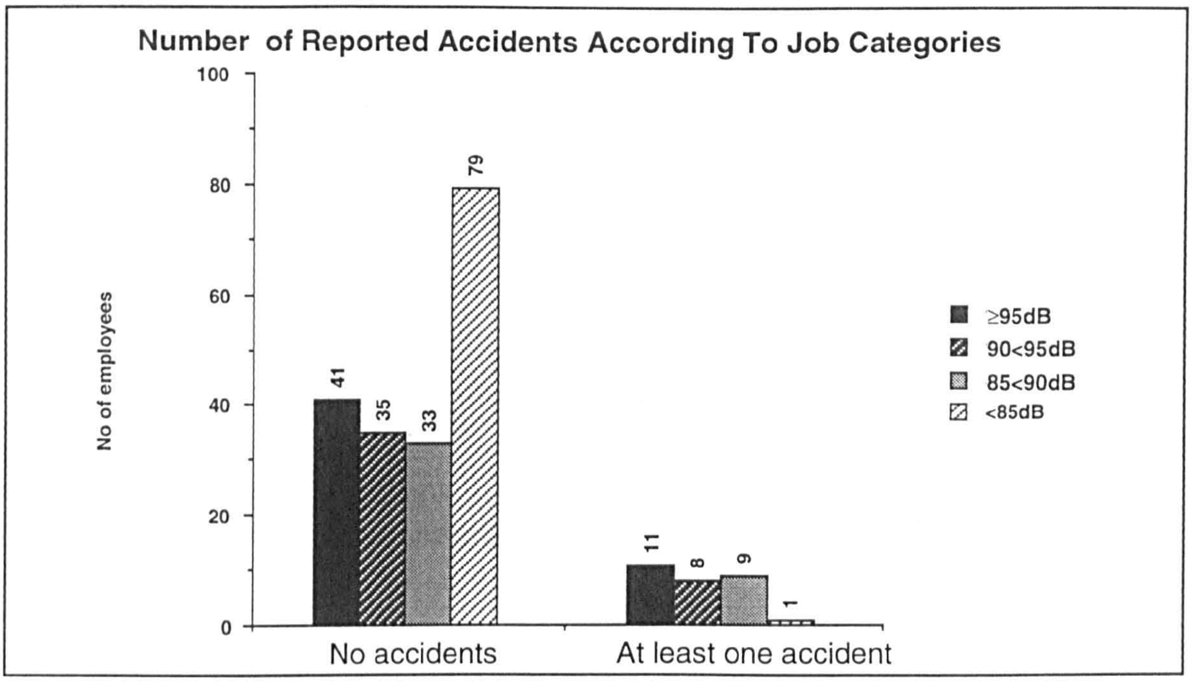
TABLE 7.3: Reported And Unreported Accidents According To Job

	Job Categories				
	≥95dB	90<95dB	85<90dB	<85dB	Total
No accidents	24	26	24	77	151
At least one acc	28	17	18	3	66
Total	42	43	42	80	217

The reported accident rate was higher in the noisier environments (See Fig 7.25). Regarding job categories with noisier levels <85dB as a control the difference between accident notes in the control areas and the noisy areas (>85dB) was statistically significant ($p<0.001$).

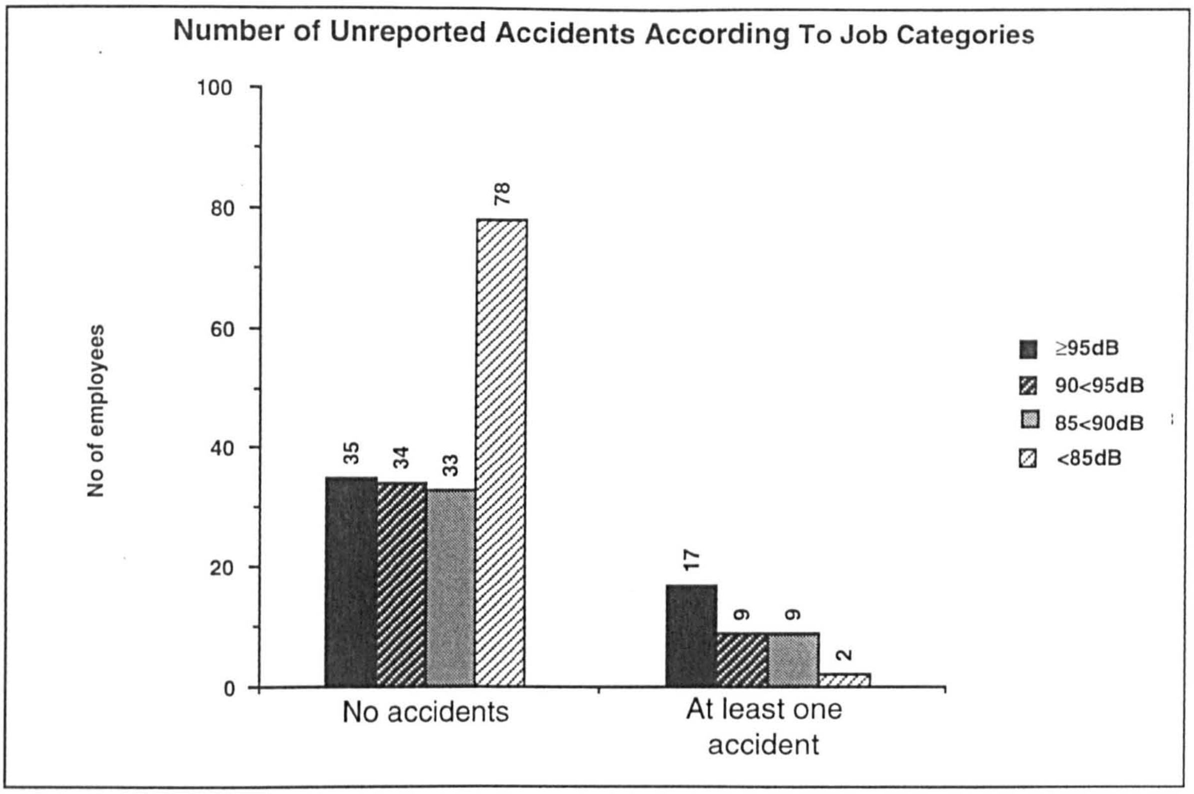
It should be noted that out of those 29 employees some of them had reportedmore than one accident .

FIGURE 7.25



The employees who did not report their accidents to management were asked why. Some felt they might lose their job or that there may be some disciplinary action, or that they would be ridiculed. The number of employees who did not report their accidents were 37, each of whom were nvolved in 6 accidents on average. Of those 37, 35 worked in a noisy environment (>85dB). The differences were statistically significant ($p>0.001$). (See Figure 7.26)

FIGURE 7.26

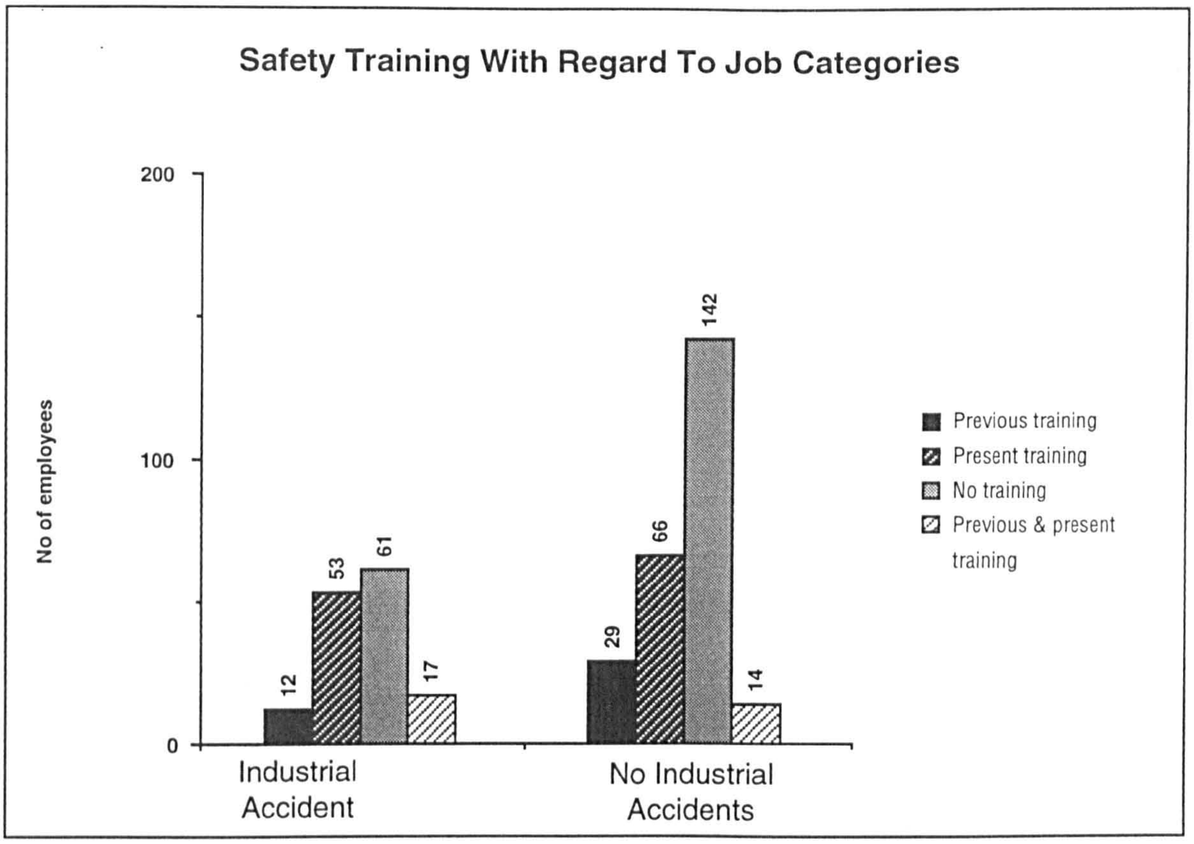


7.6.3 *Safety Training and Accidents*

In part 9 questions were addressed with regards to safety training. Most of the employees (251) had no training programme (Fig 7.27).

On the other hand those figures are not logical but the reaction of the company is to train their employees after the accident rather than before.

FIGURE 7.27



With more investigation according to job categories, training and accidents no significant results (p0.15) are shown. Category ≤95dB is an indicator for increasing accidents among the employees (see Table 7.4a), and the total number of accidents in this category is 68 (48.2%) which is almost half of the employees.

The other categories of jobs also show no significant result with (p0.78) for category 90<95dB (see Table 7.4b) and (p0.10) for category 85<90dB (see Table 7.4c). On the other hand, job category <85dB is significant (p0.00) which is mainly because the quiet environment causes the employees less distraction (see Table 7.4d). While in all, the number of accidents in this category is 5 and most of them had received training in accordance with company policy .

TABLE 7.4a: Accidents And Training According To Job Category ≤95dB

Ind Accident	Training				Row Total
	Previous	Present	None	Previous & Present	
Yes	6	20	32	10	68 (48.2%)
No	13	24	32	4	73 (51.8%)

TABLE 7.4b: Accidents And Training According To Job Category 90 <95dB

Ind Accident	Training				Row Total
	Previous	Present	None	Previous & Present	
Yes	4	13	13	4	34 (40.5%)
No	8	19	20	3	50 (59.5%)

TABLE 7.4c: Accidents And Training According To Job Category 85 <90dB

Ind Accident	Training				Row Total
	Previous	Present	None	Previous & Present	
Yes	1	18	15	2	36 (48.0%)
No	6	19	9	5	39 (52.0%)

TABLE 7.4d: Accidents And Training According To Job Category <85dB

	Training				
Ind Accident	Previous	Present	None	Previous & Present	Row Total
Yes	1	2	1	1	5 (5.3%)
No	2	4	81	2	89 (94.7%)

7.7 Warning signs within work area

The response of the employees to question 2 part 9, enquiring about their awareness of their designated area and if they satisfied with the warning signs. The response was 95% of the employees said yes and the signs were located where the noisiest areas were. On the other hand, 5% of the employees needed to be trained to recognise the warning signs because they might not wear ear protection or safety gear when required.

7.8 Noise protection equipment

All employees were satisfied with regard to ear protection supplied by the company.

7.9 Psycological and Physical Behaviour in a Noise Environment

Employees were asked if they are got enough breaks and if this affected their concentration in Question 1 Part 10. Most of the employees (352) said yes, and only 40 said no, with 2 saying they didn't know. In relation to industrial accidents and whether individuals received enough breaks, there was no significant relation between the two variables ($p>.39$). (Table 7.5)

TABLE 7.5: Accidents And Breaks

	Breaks			
Ind Accident	Yes	No	Undecided	Row Total
Yes	126	17	32	143 (36.0%)
No	226	23	2	251 (64.0%)

In Question 2 Part 10, employees asked if shifts affected their concentration. There is no apparent relation between incidents and time of shift.

Final questions addressed in Part 10 the relationship was explored between an individual feeling comfortable at work and whether or not they have been involved in any industrial accidents. The results show that more people are comfortable at work than not.

Even though a significant result (p<.00). This is because more percentage of employees who said they were unhappy during working hours reported more accidents. The accident rate in these not comfortable at work (54%) was considerably higher than the accident rate in those comfortable at work (35%). (See Table 7.6)

TABLE 7.6: The Relationship Between Comfort And Industrial Accidents

	Comfortable		
Ind Accident	Yes	No	Row Total
Yes	111	32	143 (36.3%)
No	224	27	251 (63.7%)

CHAPTER 8

CONCLUSIONS & RECOMMENDATIONS

8.1 CONCLUSIONS

Based on the results from the study at Don & Low noise has an effect among employees, eg, induced hearing loss, other ear problems, blood pressure levels, high rate of accidents, etc. The following conclusions have been reached:

1. A large number of the employees at Don & Low are exposed to a level of noise which exceeds 85dB.

2. The longer the workers are exposed (years) the more the workers are likely to suffer induced hearing loss.

3. Age can be an added factor inducing hearing loss amongst the workers.

4. Sex has no effect with regard to induced hearing loss.

5. The higher the level of noise that workers are exposed to the more accidents they are involved in.

6. The workers under-report the true number of accidents they have been involved in, especially minor ones. When interviewed they gave figures, but when asked to write these figures in the questionniare (even in the blind questionnaire with no names), they refused. There appears to be a lack of trust between the workforce and the management.

7. A large number of the workers have had more accidents than others because they have had no training courses and because of the high level of noise they have been exposed to.

8. There is statistically significant differences between noise levels and blood pressure.

9. There is a higher proportion of smokers in the noisier environments in comparisons to the control group .

10. A large number of beamers are exposed to a high level of noise because of weaknesses in the engineering design. The level of noise in the beaming department would be <75dB if the department was isolated from the weaving area. This department should be shifted to somewhere else to alleviate this problem.

11. The hearing threshold level for hazard to the individual of>85dB adopted from the Shell UK COSHA programme would appear to be appropriate for the conditions revealed in this survey of Don & Low works.

12. The Company hasn't taken advantage of their medical records in planning to protect their employees from noise.

13. There are notices explaining some of the ear problems associated with high levels of noise, eg, pain in the ears, ear infections, perforated eardrum , tennitus, vertigo and ear wax.

14. Training to prevent occupational accidents is not adeqiate because a large number of employees have had no training at all or they had it elsewhere, or they may have received training after rather than before involvement in an accident.

15. From observation all employees are wearing their personal protection, but there is no training programme to instruct the employees in how to wear this hearing protection.

8.2 Precautions

Prevention of Occupational deafness, if it is to be taken seriously, requires a decisive shift to engineering noise control. Occupational exposure limits are the first consideration. Noise should be controlled by suppression of noise at source, and also by the provision of proper hearing protection.

Courses of action include:

8.3 *Control of noise at source*

a. *Design and layout of buildings*

Noise should be considered at the planning stage and should effect choice of materials, layout of machinery, and design of machinery, in order to isolate the noisiest processes

b. *New plant and vehicles*

New plant/vehicles should at least achieve noise spec <85dBA. This should be investigated before purchase.

c. *Existing plant/processes*

Accoustic materials will help reduce noise (Teflon instead of metal at points of impact etc). Ingenuity should be used to gain most effectiveness - these noises are not inevitable and can be softened.

d. *Noise refuges*

Central refuges (cabins) are a retreat to escape general noise level and should be considered to give workers a harbour from noise (Peter B. Cook, 1993)[81].

8.4 *Personal Hearing Protection*

"Every employer shall ensure, so far as is practicable, that when any of his employees is likely to be exposed to the first action level or above in circumstances where the daily personal noise exposure of that employee is likely to be less than 90dB, that employee is provided at his request, with suitable and efficient personal ear protectors" (Health and Safety Executive, 1989).[82]

The form of hearing protection used depends on local factors. There are many protective devices available, and it is important to keep up with current trends. The decision will obviously be influenced by cost, comfort and most importantly, acceptability by the employees who have to wear them. They include:

a) *Ear muffs/hearing defenders*

Ear muffs provide the best protection. There are many designs available which offer variations in weight, headgear and materials used. Some have integral telephone communication to receive instructions in extremely noise environments. They can also be modified for use with safety helmets. Unfortunately they can be uncomfortable in hot conditions, but if damage to hearing is avoided than the discomfort should be acceptable (John Caims, 1992)[83].

b) *Ear plugs*

These are available in varying designs and materials. The level of protection is generally less than achieved by hearing defenders (they are cellular plastic, compressed befoore insertion, and then expand to conform to ear opening). They are cost-effective (cheap), and can be used on a once-only disposable basis. There is also an improved de sign which is plastic inside a smooth vinyl envelope which can be cleaned and used several times. They can also be mounted on a headpiece which allows adjustment for comfort and a higher level of protection. Plugs cannot be used where ear infection is present and in hot environments can cause infection of the skin lining of the ear.

Resistance to wearing hearing protection is common, often in the older worker or when noise hazard seems non-threatening. Health and safety staff should make every effort to produce an effective hearing conservation programme, and should choose protective devices to suit the needs of those most at risk. A hearing conservation programme should consist of:

a. Measurement of noise levels and estimation of total noise energy (industrial hygienist)
b. Regular assessment of noise levels
c. Reduction of noise levels as indicated by above measurements to a level to reduce damage to hearing (design considerations and engineering)
d. Issue of suitable hearing protection devices where noise reduction is impossible (health and safety)
e. adoption of proper standards
f. record keeping and analysis and reporting of results
g. training of personnel
h. Implentation of the programme and compliance enforcement (management and employees)

Personal hearing protection should:

a. be implemented as part of a programme
b. not be used as a substitute for not controlling noise at source
c. suit the situation
d. be suited to the individual worker and his conditions

e. be made available where noise levels are between 80-90dB

f. be compulsory where noise leels exceed85-90dB

8.5 The Acute/Chronic Effects of Noise

Very loud or sudden noise can cause a ruptured eardrum, which is extremely painful and may cause haemorrhage from the affected ear. Immediate deafness occurs, and recovery depends on the severity of exposure.

Chronic effects can be sustained when sound levels are above 85dB, and will eventually cause a deterioration in hearing in excess of that usually associated with age. Treatment should be preventative - reduce noise exposure to safe l levels, as nothing can reverse the process. Periodic measurements of sound levels should be taken and correction undertaken where necessary. If noise has to stay above 85dB protective devices should be used (Peter B.Cook, 1993)[81].

A history of previous noise exposure should be acquired from a prospective employee. Chronic ear conditions should preclude employment in areas where protection is needed. If a perforated eardrum is present then individual assessment would be required. Periodic medical examination should be carried out. Audiograms at regular intervals would provide the necessary information and lead to an assessment of noise exposure damage. Simple screening audiographs are reasonably priced and easy to operate.

Deafness discovered at periodic assessment will not necessarily be noise-induced. Reference to a specialist would establish diagnosis.

8.6 The Role of the Worker

The participation of the employee/worker is essential to the success any programme. Without it the programme is doomed to failure. He must be made aware of hazards, taught how to use safe working practices and given the facilities to carry this out. He should be made aware that continuous levels of noise over long periods of time are hazardous to hearing (Jeyaratnam, J., 1992).[17]

8.7 Recommended Standards

Company standards should meet local statutory requirements. Where such requirements are not available or are considered inadequate the following standards are a guide:

a. The personal equivalent continuous noise level should not exceed 85dB(A) over a working day. No adaptation is required for shift lengths in excess of 8 hours/day, 40 hours/week, or occasional overtime work, provided exposure time over a year does not exceed a total of 2000 hours

b. No person should enter areas where steady noise levels are above 115dB(A) or impulse noise levels are above 135dB(A), no matter how briefly, without the proper use of hearing protectors

c. Maximum sound pressure limit for plant and equipment design is 85dB(A) measured at 1 metre. The objective is to maintain work area noise below 85dB(A) (Health and Safety Executive, 1989)[82].

8.8 Assessment of Noise Levels/Doses

"Every employer shall, when any of his employees is likely to be exposed to the first action level or above, or to the peak action level or above, ensure that a competent person makes a noise assessment which is adequate for the purposes of:

a) identifying which of his employees are so exposed;

b) providing him with such information with regard to the noise to which those employees may be exposed as will facilitate compliance with his duties under regulations 7, 8, 9 and 11"(Health and Safety Executive, 1989)[82] (Forst, G P, 1992)[84], (Shell, Safety and Health Committee)[47]

The steps of the assessment of noise levels and noise doses are:

a) Identify and map areas where steady noise levels exceed 80dB(A)
b) Signpost these areas and mark tools/equipment where levels exceed 90dB(A). Hearing protectors will be mandatory inside these areas.
c) In areas where noise levels are betwen 85-90dB(A): there are two options signpost area and mark tools and equipment at 85dB(A) and instruct the mandatory use of hearing protection for all persons entering the area, or, specify in the work permit when hearing protection must be used to ensure that daily dose is not exceeded
d) Areas where noise levels do not exceed 85dB(A) require no specific measures
e) Update assessments every 5 years
f) Establish baseline for comparison with future assessments to allow check to be kept on levels in noise reduction

Assessments obviously have to made by a competent person, who will be able to supervise collection of information on noise levels etc and use this in a final assessment.

8.9 Investigation/follow-up of Injuries and Accidents

Guidelines for accident investigation are (Shell, Safety and Health Committee)[47]:

a. Investigate promptly
b. Talk to those persons who have a thorough knowledge of the work situation

c. Gather relevant facts such as similar accidents recorded and any information which may help to pinpoint cause
d. Try to identify cause
e. Recommend actions to avoid further incidents
Lessons learned should be communicated back to employer.

Hold safety meetings which will help to:

a. Eliminate any unsafe practices
b. Keep employees up to date with safety information
c. Try and obtain suggestions/contributions from employees, therefore hopefully gaining their commitment to a safety programme and actively encourage debate, ultimately resolving any concerns on both the employers and employees side

8.10 Following recommendations apply to various Don & Low plants.

Note that the recommendations for each plant are listed under the names of individual plants:

1. Newford Park Works
2. St James Works
3. Canmor Works
4. Wallace Works

Various factors common to all sites are noted on the following pages.

8.10.1 CRITERIA FOR RECOMMENDATIONS

Recommendations are based on current legislation and good occupational hygiene practice. Recommendation for engineering noise control has been done in co-operation with Shell Noise Surveyors, engineers, co-ordinators, maintenance, machine operators and managerial staff at Don & Low. Criteria used to indicate priorities are:

8.10.2 BASIS OF RECOMMENDATION

The recommendations made may be categories under a number of headings:

1. Limits — These aim at meeting Occupational Exposure Limits set by the Health and Safety Executive, Shell Internal Working Limits or relevant standards.

2. Safety — These aim at minimising physical hazards which may lead to injury.

3. Policy — These aim at bringing existing practices into line with Company Policy or standing orders.

4. Regulatory — These aim at meeting a specific Act of Parliament, Regulation or Approved Code of Practice.

5. Control — These aim at adopting generally accepted principles of control which can be used to minimise exposure.

8.10.3 GENERAL RECOMMENDATIONS

1 DETERMINE NOISE DOSES OF DAY WORKERS

This is aimed at providing data so the risk to health can be fully evaluated.

2 MAINTAIN THE EXISTING PRACTICE OF THE PROVISION OF A CHOICE OF HEARING PROTECTORS SUITABLE FOR THE JOB AND APPROVED BY THE SITE SAFETY/TRAINING SUPERVISOR.

This is aimed at ensuring that noise levels at the ear do not exceed 80dB(A).

3 CHECK THAT INFORMATION, INSTRUCTION AND TRAINING IS GIVEN ON CONTROL OF EXPOSURE TO NOISE.

This is to ensure proper use of control methods and procedures and should include:-

a. the results of the workplace assessment;
b. work associated noise induced hearing loss;
c. jobs and tasks where exposure is likely to occur;
d. company standards for hearing conservation;
e. company measures to control noise on the particular jobs and tasks;
f. selection, use and maintenance of personal hearing protectors
g. signposting of areas and marking of equipment and tools where noise levels exceed 85 and 90 dB(A);
h. the requirement for mandatory use of hearing protection where signs require such use

4 REVIEW NOISE EXPOSURES AND AREA LEVELS AT LEAST EVERY FIVE YEARS OR IF THERE IS ANY CHANGE WHICH IS LIKELY TO AFFECT EXPOSURES. UPDATE THE NOISE ASSESSMENT.

This is aimed at ensuring the assessment of risk remains valid.

5 CONSULT THE COMPANY MEDICAL ADVISER AS TO THE REQUIRED FREQUENCY FOR AUDIOMETRY.

This is aimed at reducing the requirement for audiometry in line with recommendations in the Shell Noise Guide[47].

6 KEEP RECORDS.

This is to ensure access and retrieval of information, including:-

a. assessment (including measurement) of sound levels and noise doses;
b. noise control measures;
c. individual cases of noise induced hearing loss;
d. information and training programmes;
e. issue of hearing protection.
f. documentation of investigation into the availability of quieter equipment.

7 REPORT THE EFFECTIVENESS OF THE COMPANY'S HEARING CONSERVATION PROGRAMME TO SHELL CHEMICALS.

This is in order to comply with the Shell Noise Guide[47] and should include:

a. the number of people who are likely to receive a personal noise dose above 80 dB(A) over a normal working day;
b. the number of people with work associated noise induced hearing loss as defined by national criteria.
c. the number of people whose work associated noise induced hearing loss has increased since their previous audiogram.

8 ADOPT A MORE STRUCTURED APPROACH TO THE IMPLEMENTATION OFTHE HEARING CONSERVATION PROGRAMME. PREPARE AND EXECUTE AN IMPROVEMENT PLAN BASED ON THIS REPORT.

This will ensure steady improvement in the control of noise as far as is reasonably practicable.

9 DEVELOP THE EXISTING COMPANY POLICY REGARDING THE HEALTH AND SAFETY ASPECTS OF NEW EQUIPEMENT TO INCLUDE THE PURCHASE OF QUIETEST EQUIPMENT AVAILABLE BEARING IN MIND REASONABLE PRACTICABILITY.

This is aimed at reducing the noise at source.

10 INTRODUCE "TOOL BOX" TALKS

These are meetings aimed at involving management and workforce to facilitate an understanding of noise sources and may initiate appropriate methods of control.

11 DOCUMENT THE EXISTING ELEMENTS OF THE COMPANY'S HEARING CONSERVATION PROGRAMME AND THE INFORMATION FROM THIS STUDY AS AN ASSESSMENT OF THE RISK TO HEALTH AND A REVIEW OF THE CONTROLS ON EXPOSURE.

This is aimed at ensuring that the company discharges its duty under the Noise at Work Regulations 1989 and is in line with Shell policy under the Shell UK Ltd. COSHA Programme.

8.10.4 RECOMMENDATIONS TO NEWFORD PARK WORKS, DON & LOW LTD, FORFAR

1 INVESTIGATE THE EXCESSIVE VIBRATION ON THE DRIVE MOTOR ON THE EXTRUDER ON LINE 21 AND TAKE APPROPRIATE ACTION

This is aimed at rectifying the fault before the noise level increases.

2 FIT THE EXHAUSTS OF THE INTERMEDIATE POLYMER PUMPING STATIONS WITH AN ADDITIONAL TUNED SILENCER

This is aimed at reducing the noise at source.

3 ISOLATE FAN UNITS ON LINES 56 AND 57 FROM FLOOR USING ANTI-VIBRATION MOUNTINGS AND FIT FLEXIBLE COUPLINGS TO DUCT WORK

This is aimed at reducing the noise at source by reducing vibration.

4 REVIEW ALTERNATIVES TO AIR GUNS FOR THE COLLECTION OF LOOSE THREADS DURING DOFFING OR THREAD BREAKS

This is aimed at reducing exposure by elimination of the noise sources.

5 INVESTIGATE ALTERNATIVE NOZZLE SHAPES FOR AIR GUNS (i.e. A BELL SHAPED INLET)

This is aimed at reducing the noise at source by reducing air turbulence.

6 INVESTIGATE ALTERNATIVE MATERIALS FOR AIR GUN BAGS, SUCH AS FINE WEAVE, PILED CLOTH

This is aimed at attenuating the noise from the collecting bag.

7 INVESTIGATE THE USE OF PLASTIC LINERS TO THE ALUMINIUM TUBE CENTRES

This is aimed at reducing noise at source.

8 FIT A RUBBER LINED TAKE OFF CHUTE FOR THE TUBE RECOVERY MACHINE

This is aimed at limiting metal to metal impact noise that occurs when the tube leaves the machine and hits the chute and other tubes in the take off bin.

9 RELOCATE ALL ROTATING EQUIPMENT POSITIONED ON THE METAL PLATING OVER SERVICE DUCTS ONTO THE CONCRETE FLOOR AND ISOLATE

This is aimed at isolating the noise source and minimising vibration of the equipment and metal plating.

10 DO NOT ALLOW THE USE OF LARGE AIR GUNS WHERE SMALL AIR GUN CAN BE USED

This is aimed at reducing the noise exposure by the use of quieter equipment.

11 INVESTIGATE THE SOURCE OF NOISE ARISING FROM THE EXTRUDER ON LINE 18 AND TAKE APPROPRIATE REMEDIAL ACTION

This is aimed at reducing the noise at source.

8.10.5 RECOMMENDATIONS TO ST JAMES, DON & LOW LTD, FORFAR

1 EVALUATE THE EFFECT OF OPERATING LOOMS ABOVE DESIGN CRITERIA ON EXPOSURES

This is aimed at reducing exposure by reasonable practicable means.

2 LIAISE WITH THE LOOM MANUFACTURERS WITH A VIEW TO NOISE REDUCTION AT SOURCE

This is aimed at reducing noise levels at source.

3 CONSIDER FITTING A WALL BETWEEN THE LOOMS AND THE BEAMING AND INSPECTION AREAS

This is aimed at reducing the transmission of noise from the looms to other workareas.

4 ENSURE THAT WORKERS USE HEARING PROTECTION IN ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS. RETRAIN ALL EMPLOYEES EXPOSED TO NOISE

This is aimed at prevention of misuse of equipment such the removal of the plastic coating of ear plugs and using the fibre only for hearing protection.

8.10.6 RECOMMENDATIONS TO CANMOR WORKS, DON & LOW LTD, FORFAR

1 REVIEW THE AVAILABILITY OF ALTERNATIVE QUIETER PROCESS TO DREF SPINNING

This is aimed at reducing noise at source.

2 LIAISE WITH THE LOOM MANUFACTURER WITH A VIEW TO NOISE REDUCTION AT SOURCE

This is aimed at reducing noise levels at source.

3 CONSIDER FITTING A WALL BETWEEN THE WEAVING AREA AND THE FINISHING AREA

This is aimed at reducing the exposures of the finishers by isolation from the noise of weaving looms.

4 ONLY USE HEARING PROTECTORS APPROVED BY THE SITE SAFETY/TRAINING SUPERVISOR

This is aimed at ensuring the equipment provided is fit for the purpose.

5 POST WARNING SIGNS INDICATING THAT HEARING PROTECTION IS REQUIRED IN THE FINISHING AREA.

This is to comply with the Shell Noise Guide and represents good practice.

6 ENFORCE THE USE OF HEARING PROTECTORS IN THE FINISHING AREA

This is aimed at reducing the noise induced hearing loss to below that of the first Shell Action Level of 80 DB(A).

7 EVALUATE THE EFFECT OF OPERATING LOOMS ABOVE DESIGN CAPACITY ON EXPOSURES

This is aimed at reducing noise at source as far as is reasonably practicable.

8.10.7 RECOMMENDATIONS TO WALLACE WORKS, DON & LOW LTD, PERTH

1 LIASE WITH THE LOOM MANUFACTURERS WITH A VIEW TO NOISE REDUCTION AT SOURCE.

This is aimed at reducing noise levels at source.

2 CONSIDER FITTING A WALL BETWEEN THE LOOMS AND THE BEAMING AND INSPECTION AREAS.

This is aimed at reducing the transmission of noise from the looms to other work areas.

3 FIT DOORS TO WORKSHOP.

This is aimed at reducing the transmission of noise from the production area.

4. EVALUATE THE EFFECT OF OPERATING LOOMS ABOVE DESIGN CRITERIA ON EXPOSURES.

This is aimed at reducing exposure by reasonable practicable means.

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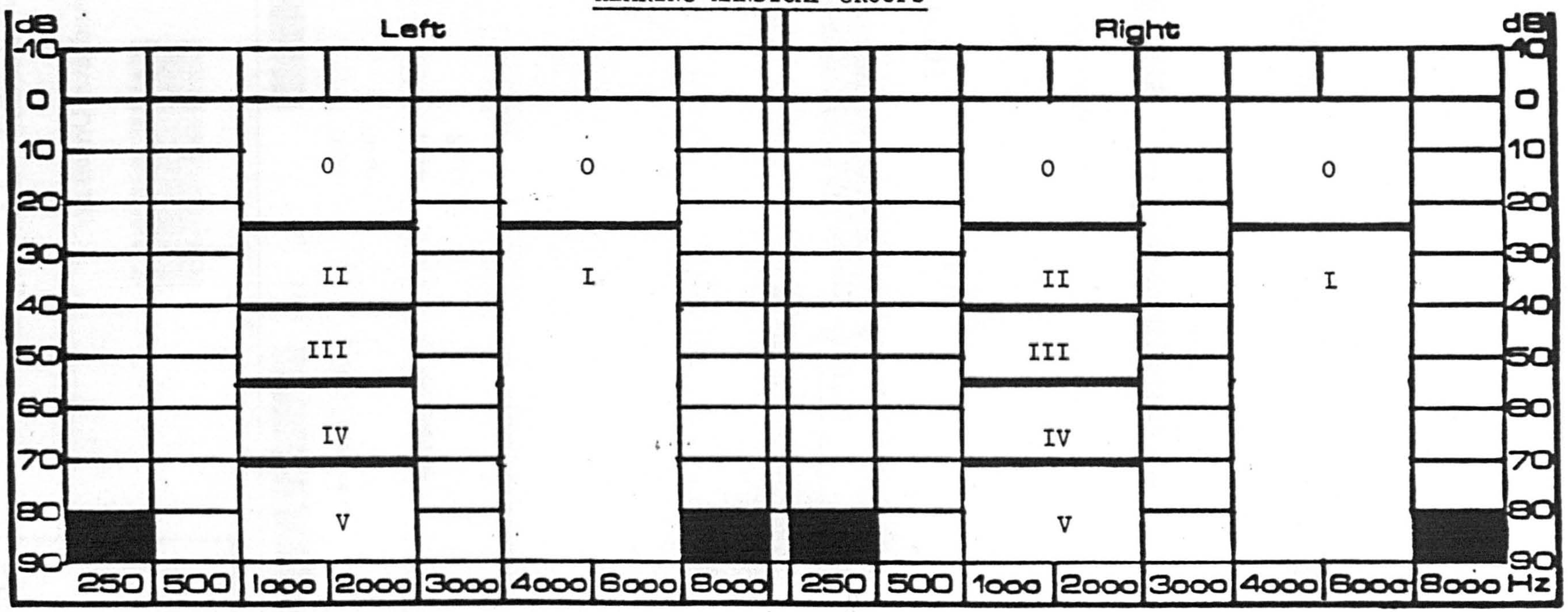
BUPA OCCUPATIONAL HEALTH

OVERLAY NO. 1

HEARING HANDICAP GROUPS



ASSESSMENT

1) Always assess better ear.
2) If poorer ear exceeds better ear by more than 40 dB raise final assessment to next higher group
3) Assess average hearing level

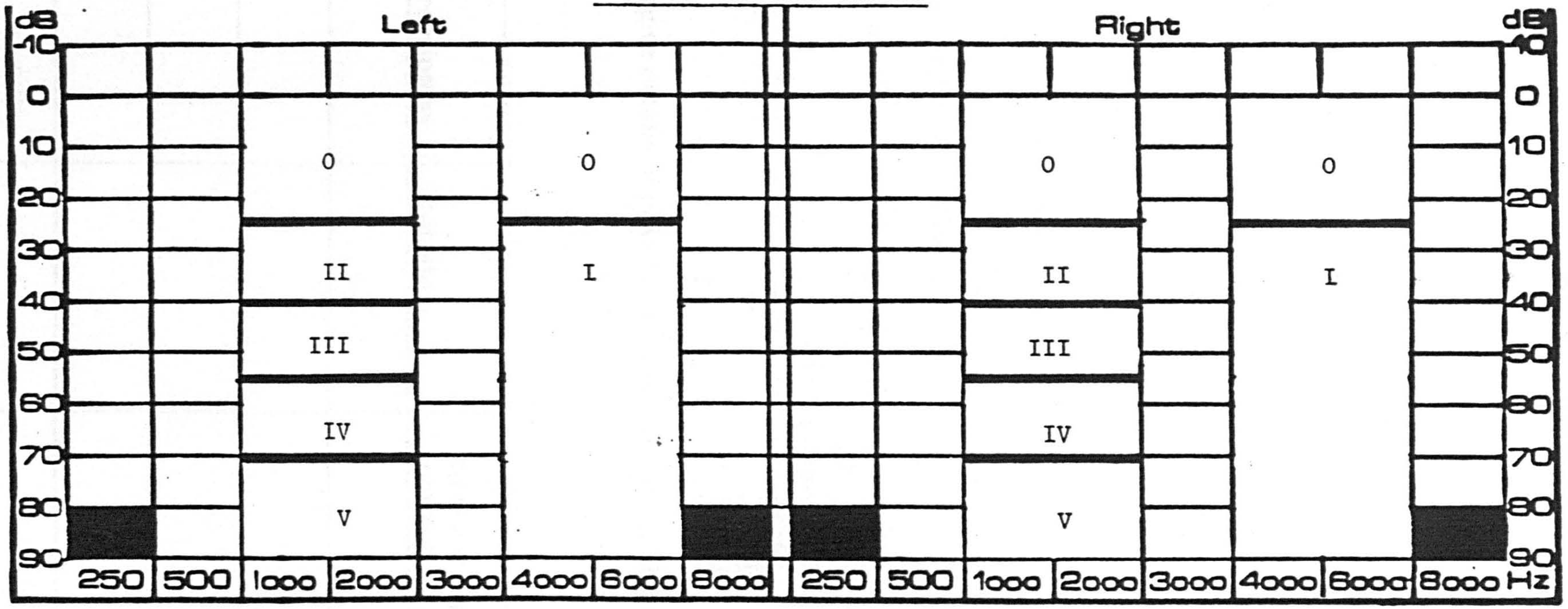
Based on "Industrial Audiometry" by Bryan and Tempest

Appendix 1

BUPA OCCUPATIONAL HEALTH

OVERLAY NO. 1

HEARING HANDICAP GROUPS



ASSESSMENT

1) Always assess better ear.
2) If poorer ear exceeds better ear by more than 40 dB raise final assessment to next higher group
3) Assess average hearing level

Based on "Industrial Audiometry" by Bryan and Tempest

Appendix 2

QUESTIONNAIRE

Health and Safety Survey on the Effects of Noise in the Workplace

PART 1

Name ....

Date of Birth .... Male/Female ....

Job description .... Employee Number ....

PART 2 (Please tick your answer where appropriate)

1)	Residence:	a)	Previous	( )	Town	( )	Country
		b)	Present	( )	Town	( )	Country

2) Distance to work in miles ....

3) Means of travel
( ) a) Private car
( ) b) Bus (coach)
( ) c) Other (please specify) ....

PART 3

1) Please give details of past employment (including details of present job)

Job Description	Duration	Shifts of work (day, night, both or irregular)
1		
2		
3		
4		
5		

2) During your past and present job, how long have you had to work in a noisy environment where you had to shout to be heard when at a distance greater than two metres?

( ) Never;
( ) Less than one year;
( ) One year to less than five;
( ) Five years to less then ten;
( ) Ten years to fifteen years;
( ) Other (please specify) .... Years

PART 4

1) Do you find it difficult to follow a conversation if there is back-ground noise e.g. T.V., radio, children playing?

( ) Yes ( ) No

2) Can you follow the television news when the volume is turned up only enough to suit other people?

( ) Yes ( ) No

3) Can you hear a watch ticking when it is held to your:

a) Right ear
( ) Clearly
( ) Not very well
( ) Not at all

b) Left ear
( ) Clearly
( ) Not very well
( ) Not at all

PART 5 - EFFECTS ON HEARING

1) a) Have you ever been exposed to gunfire or explosions that could affect your hearing?

( ) Yes ( ) No

b) Was it regular exposure?

( ) Yes ( ) No

2) a) Have you ever been exposed to loud noises during your leisure activities e.g. (Loud music, ear phones, etc.)

Please list ....

....

b) Was it regular exposure?

( ) Yes ( ) No

PART 6

1) Have you had any of the following ear problems?

a)	Pains in the ears	( ) Yes ( ) No
b)	Running ears	( ) Yes ( ) No
c)	Abscess in ears	( ) Yes ( ) No
d)	Ear infection	( ) Yes ( ) No
e)	Ear injury	( ) Yes ( ) No
f)	Perforated eardrum	( ) Yes ( ) No
g)	Noises (Tinnitus) in ears	( ) Yes ( ) No
h)	Have you had any operations on your ears	( ) Yes ( ) No
i)	Suffered from dizziness (Vertigo)	( ) Yes ( ) No
j)	Have you ever suffered from wax in the ears	( ) Yes ( ) No

PART 7

1) Have you had any of the following health problems?

a)	Sleep disturbance	( ) Yes ( ) No
b)	Annoyance (e.g. headache and mood changes)	( ) Yes ( ) No
c)	Blood pressure	( ) Yes ( ) No
	i) Are you on medication	( ) Yes ( ) No
	ii) Is it hereditary	( ) Yes ( ) No
d)	Do you smoke	( ) Yes ( ) No
e)	Are you a former smoker	( ) Yes ( ) No

PART 8

1) a) Have you ever had any industrial accident?

( ) Yes ( ) No

b) If yes, how many times ....

PART 9

1) Have you any safety training related to noise before you started your job?

( ) Previous job ( ) Present job ( ) Ever

State ....

....

2) Are the noise warning signs well located within your work area?

( ) Yes ( ) No

3) Does your employer supply you with noise protection equipment?

( ) Yes ( ) No

4) Types of ear protection used
( ) None
( ) Plugs
( ) Muffs
( ) Other

PART 10

1) Do you get enough breaks during your work shift?

( ) Yes ( ) No

If No, please give your comments

....

....

2) Which shift do you prefer to work in?

( ) Morning
( ) Afternoon
( ) Night

3) Do you feel comfortable during working hours?

( ) Yes ( ) No

1, ..., hereby give my permission for, Faaisal Al-Sharifi, to be given access to my audiometry Test Results. All information extracted will be strictly confidential.

Signature .... Date ....

Appendix 3

Health and Safety Survey on the Effects of Noise in the Workplace

QUESTIONNAIRE

Further to the questionnaire sent out some weeks ago, I now require further details and would be obliged if you would cooperate by completing the questions below. The results of the study could help Don & Low to provide a healthier and safer working environment for the benefit of all.

PART 1

Age .... Male/Female: ....

Job Description: ....

PART 2

(i) How long have you worked at Don & Low? .... Years

(ii) How many industrial accidents have you been involved in? ....

(iii) How many of the above industrial accidents ocurred during the period 1.8.93 to 31.7.94? ....

(iv) How many of these accidents were:-

(a) reported ....

(b) not reported ....

(iv) Please detail any hearing problem you experienced during the period 1.8.93 to 31.7.94

RETURN TO: FAISAL AL-SHARIFI, HEAD OFFICE